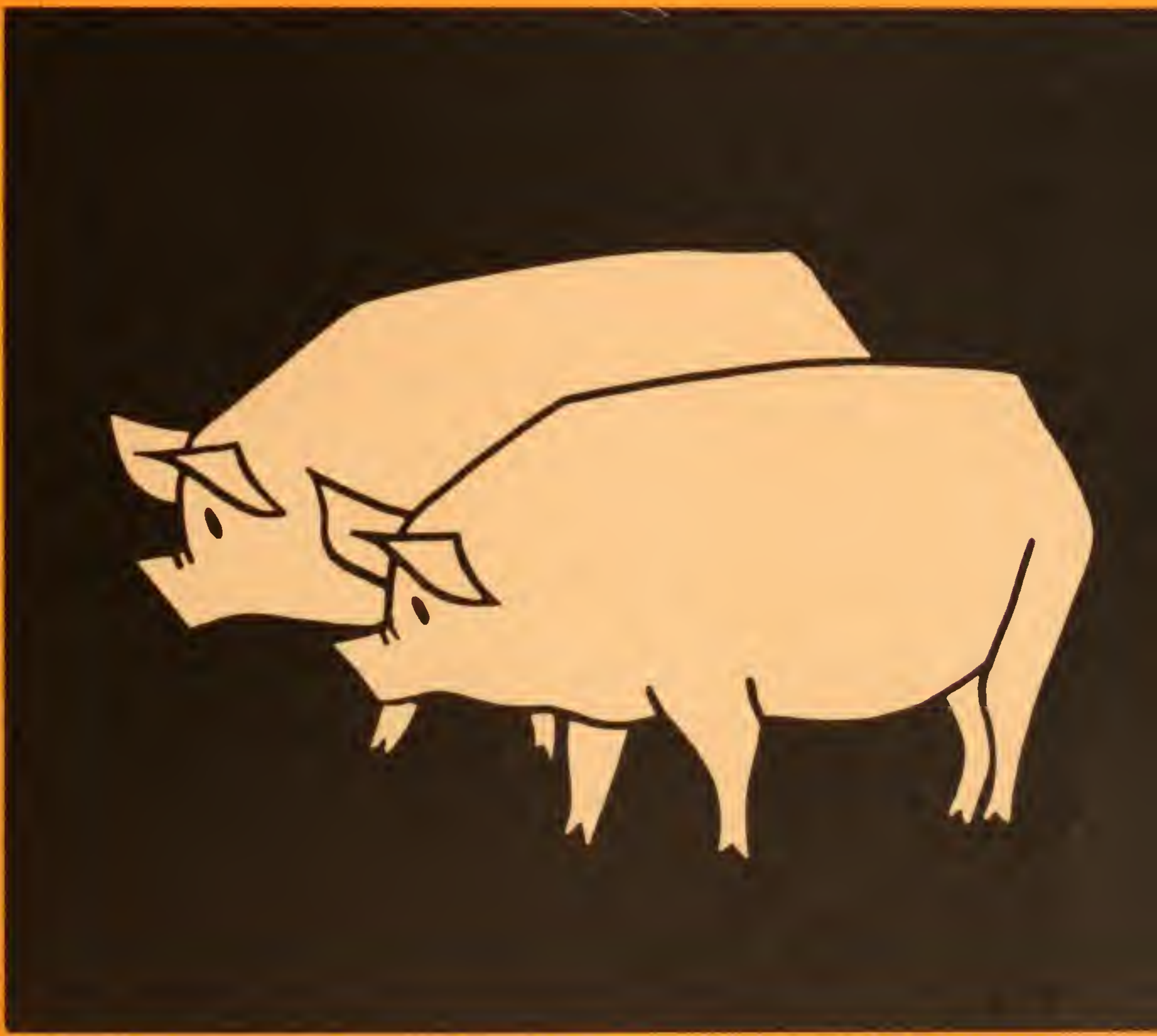
PUBLICATION 1451

CONFINEMENT SWINE HOUSING



Agriculture Canada

This bulletin was prepared in cooperation with the Swine Housing Sub-committee of the Canada Plan Service, and is complementary to swine building and equipment plans also prepared under the guidance of this committee. To obtain descriptive leaflets and detailed swine plans prepared by the Canada Plan Service, contact the engineering specialist at your provincial department of agriculture.

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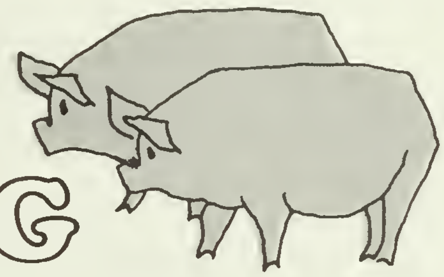

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FOREWORD

The climate of Canada is too severe for successful swine production in open feedlots or cheap, open-front buildings as sometimes practiced farther south. Winter temperatures in a large part of the swine-producing agricultural areas can drop to $-35°C$ or colder, and in summer hot periods the temperature can go to a humid $+35°C$.

The naked, non-sweating pig needs protection from these climatic extremes. This means environmental control, including temperature, humidity, airflow, light, feed and water as well as protective confinement. This publication is a compilation of research results, producer experience, and engineering practice. It is for the guidance of Canadian swine farmers planning to build new swine housing facilities or to remodel and improve existing buildings for swine. The information is prepared as an engineering supplement to other Canadian bulletins covering various aspects of swine production such as nutrition, health, breeding and production economics.

I. WHY RAISE PIGS IN CONFINEMENT?

The baby pig is born almost naked, and for about a week after birth he is very sensitive to cold. During this sensitive period he requires a temperature of about 28°C to maintain his body temperature. The sow, however, prefers 13°C to 21°C and suffers badly if the entire farrowing room is heated over 26°C for the comfort of the newborn pigs. Farrowing pens should therefore be divided into 'sow' and 'creep' areas with extra heat supplied to the creep area when required (see Chapter VII).

After the first week, temperature is less critical for the piglets. Creep temperature can then be gradually reduced. However, growing pigs even at market weight are still much more sensitive to temperature than other domestic animals having thick coats of hair, wool or feathers. Tables 1 and 2 show results of California research with two to five pigs in a controlled environment chamber.

TABLE 1. EFFECT OF AIR TEMPERATURE ON RATE OF GAIN WITH SWINE (REF. 1)

Mean live weight, kg	Average daily gain, kg/(pig-day), at air temperatures of						
	5°C	10°C	15°C	20°C	25°C	30°C	35°C
45		0.63	0.71	0.87	0.90	0.73	0.40
68	0.58	0.67	0.79	0.95	0.87	0.64	0.22
91	0.55	0.72	0.85	0.99	0.84	0.55	0.03
113	0.52	0.76	0.92	0.96	0.78	0.45	−0.15
136	0.50	0.80	1.00	0.95	0.72	0.35	−0.36
159	0.47	0.86	1.05	0.93	0.67	0.26	−0.55

TABLE 2. EFFECT OF AIR TEMPERATURE ON FEED CONVERSION WITH SWINE (REF. 2)

Live weight kg	Feed conversion, kg feed/kg gain, at air temperatures of						
	5°C	10°C	15°C	20°C	25°C	30°C	35°C
32 to 65	4.8	4.4	3.7	2.8	2.6	5.5	7.8
75 to 118	10.0	5.1	3.7	4.0	4.2	9.0	

Tables 1 and 2 demonstrate that growing pigs can respond dramatically to good housing with controlled environment. Table 1 shows that the optimum temperature for growth is about 25°C for 45 kg pigs. As they grow to market weight the optimum temperature remains near 20°C but, unlike smaller pigs, lower temperatures (down to 15°C) do not reduce growth rate appreciably (see shaded areas in tables 1 and 2). Note especially in Table 1 that older pigs actually lose weight at temperatures of 35°C and above, and that the larger a pig gets, the more it suffers from too much heat.

Table 2 showing feed conversion is even more significant to the hog producer. The growing pig (32 to 65 kg) is more efficient at 25°C and the finishing pig shows the best feed conversion at 15°C. Temperatures below 15°C reduce feeding efficiency considerably, but temperatures above 30°C are much more serious. Remember also that these tests involved groups of two to five pigs in a large pen. Pigs housed under typical farm conditions would be more crowded in larger groups and would suffer even more from excessive heat.

Michigan research (see Table 3) has similarly demonstrated the advantages of an insulated, fan-ventilated building over open housing for finishing swine, even in the summer.

Considering pig environment only, it is less important to house the adult breeding herd in controlled-environment buildings, but other considerations are important for this group. Reproductive performance of sows and boars depends on careful observation, positive identification and easy handling of individuals by the herdsman. Feed intake of sows and boars should be controlled to prevent excess fat. Sows must be confined as individuals, or in small groups of compatible individuals.

In summary, these facts indicate that the best swine housing system for Canadian climatic conditions consists of several specialized buildings. Each building should be designed to suit the particular needs of the

TABLE 3. RESULTS OF MAY-SEPTEMBER FEEDING TRIAL WITH HOGS (REF. 3)

	Type of housing provided		
	Open-front shelter with concrete lot	Insulated, fan-ventilated	Insulated, ventilated and air-conditioned
Average daily gain, kg	0.67	0.74	0.73
Average feed consumption, kg/(pig-day)	2.54	2.59	2.49
Feed conversion, kg feed/kg gain	1.72	1.58	1.55

age-group to be housed. All buildings in the swine production system should be well insulated and equipped with mechanical ventilation (and in many cases supplemental heating), to provide automatic control of the air environment. Even where the temperature requirements are similar between age-groups in the production cycle, it is desirable to isolate age-groups in separate rooms or buildings in order to control disease.

II. CONFINEMENT SWINE PRODUCTION SYSTEMS

Figure 1 shows typical growth of well-bred pigs from birth to market weight, under conditions of good health, good nutrition and optimum environment (Ref. 4).

According to current practice, this growth period is divided into four stages: nursing (birth to weaning), weanling (after weaning), growing and finishing. Each of these housing stages has very special requirements for heating and ventilation, protection and confinement, feeding and watering devices, and waste removal. In a typical swine production system, the pig is being housed through his full life cycle and facilities must be designed especially to meet the requirements of each growth stage. Except in small swine production units (under 20 sows), attempts to combine all of these widely different housing requirements into one simple pen unit have resulted in compromise, with greater total housing costs.

The overlapping of these stages in Figure 1 illustrates accepted variations from one housing system to another. For example, the nursing stage may end at 3 weeks by removing the sow from the farrowing-nursing pen, with the pigs remaining in the pen as weanlings, starting at about 5 kg. Or the farrowing-nursing pen may be large enough for the sow and litter up to 6 weeks, at which time the 10 to 13 kg pigs graduate to weanling stage.

The weanling stage may be terminated at 18 to 24 kg (around 10 weeks of age), when the pigs are moved to another area to accommodate their increasing space requirements and changing ration.

The growing stage may end at 45 to 65 kg, at which time the pen groups are split to increase floor space and sometimes to allow restricted feeding for the finishing stage. As shown in Table 4, growing and finishing stages usually share the same building unit.

The design of swine production systems is made easier by thinking of each repeating group of steps in the process as a *cycle*. Table 4 includes several cycles involved in swine production. Each cycle repeats in a different period of time, and these cycle times will be used later to calculate numbers of pens, building area requirements, and rates of pig production. For example, one of these cycles is shown in Table 4, under 'Housing Stage'; this involves the feedback of selected gilts from 'finishing' to 'breeding', to build up the breeding herd and to replace unproductive cull sows.

THE SOW BREEDING CYCLE

This is another cycle shown first in Table 4. This cycle includes breeding, gestation, prenatal and nursing stages, and it repeats when sows return to breeding. This cycle is based on the sows' natural ovulation cycle (3 weeks) the gestation period (about 16 weeks) and the nursing period (usually 3 to 6 weeks).

Following weaning at the end of nursing stage, most sows will ovulate in 4 to 8 days time. During this breeding stage sows are frequently irritable and many managers want special pens or individual stalls different from the group pens they use for gestation housing. Table 4 shows 4 weeks for breeding since it is normal to leave sows in breeding housing until at least 3 weeks after first breeding, in case they fail to conceive the first time. Therefore, only 12 to 15 weeks of the 16-week gestation period would be spent in gestation housing; the final week of gestation, called the prenatal stage, is spent in the farrowing pen to familiarize the sow with her new confinement.

Table 5 shows the important sow breeding cycle in more detail. In this table each breeding cycle is considered to start at weaning date, because for most breeds (except Lacombes) ovulation usually follows weaning within 4 to 8 days. Weaning therefore can be used to time the breeding cycle, for more precise herd management.

Table 5 shows how the length of the sow breeding cycle is changed from 20 to 23 to 26 weeks, depending on nursing period and whether the sow conceives on first or second breeding. These breeding cycle times would fit probably 80% of the sows in a breeding herd; the remaining 20%, together with the gilts, would breed at random. These breeding cycle times were converted to cycles per year by dividing into 52 weeks per year, thus:

$$\frac{52 \text{ weeks/year}}{20 \text{ weeks/cycle}} = 2.6 \text{ breeding cycles/year}$$

Many sows in a herd would not achieve 2.6 breeding cycles (or litters) per year, and some sows would not reach 2.26 cycles either. For the 3-week nursing period an estimated average of 2.3 cycles per year will be used in later calculations; for the 6-week nursing period, 2.1 breeding cycles per year will be used. These figures give optimistic goals for the herdsman striving to improve his herd performance. They also ensure that

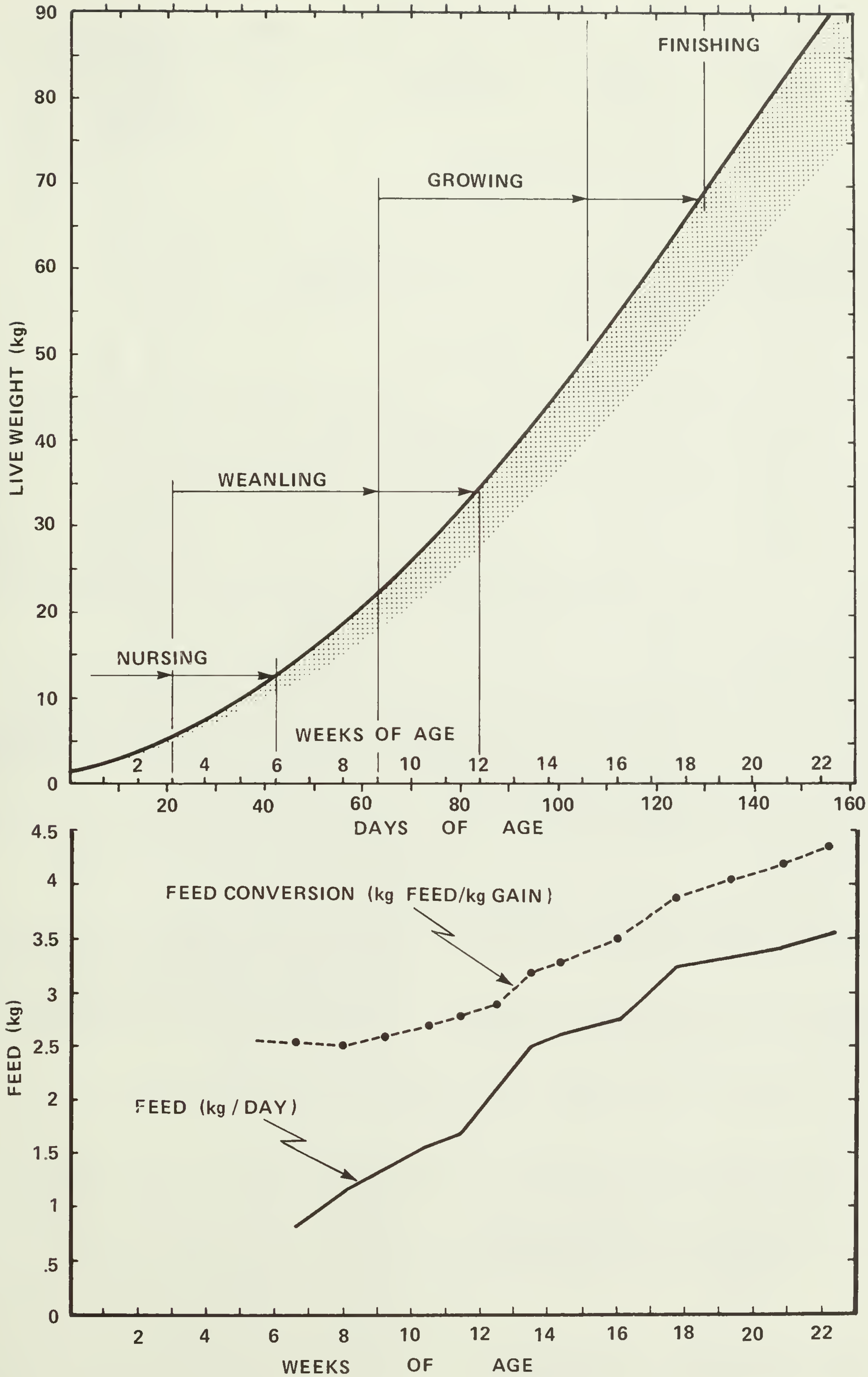


Figure 1. Growth stages, live weight and feed requirements for growing pigs.

TABLE 4. SWINE CONFINEMENT PRODUCTION SYSTEM

Housing stage	Typical duration (weeks)	Pen space (Ref. 5) (m^2/pig)	Groupings for building systems: 4 areas	3 areas	2 areas
Breeding	4	1.8			
Gestation	12 to 15	1 to 1.8			
Prenatal	1	3.5* to 5.4**			
Nursing	6 to 3				
Weanling	3 to 9	0.2 to 0.3			
Growing	9 to 3	0.35 to 0.5			
Finishing	5 to 9	0.7 to 1.0***			
to Slaughter					

Selected gilts to breeding

Sows return

* This allows for a 1.5 X 2.25 m farrowing stall for one sow and litter; this is suitable only for early weaning (at 3 weeks).

** This allows for a 1.5 X 3 6 m farrowing pen, including 1.5 X 0.6 m front creep; this is suitable for 6-week nursing period and can be used for weanling housing as well (three-area building system).

*** Allow this extra space in hot weather and for pigs to be finished to the higher market weights (about 100 kg live) permitted under the new Canadian grading rules introduced January 1978.

farrowing space will still be adequate when better breeding herd performance is achieved.

Some operators may prefer to breed at the second heat period, depending on the condition of the sow, and especially with early weaning. This increases the typical breeding time in Table 4 from 4 to 7 weeks, and reduces the average breeding cycles per year in Table 5. This in turn requires more breeding housing space and fewer farrowing pens.

TABLE 5. SOW BREEDING CYCLES

Early weaning (3 weeks)			Late weaning (6 weeks)		
	Week no.			Week no.	
Wean	0		Wean	0	
Breed	1		Breed	1	
	2			2	
	3			3	
	4	Re-breed if required		4	Re-breed if required
	5			5	
	6			6	
	7			7	
	8			8	
	9			9	
	10			10	
	11			11	
	12			12	
	13			13	
	14			14	
	15			15	
Enter farrowing	16		Enter farrowing	16	
Farrow	17		Farrow	17	
	18			18	
	19	Enter farrowing		19	Enter farrowing
Wean	20	Farrow		20	Farrow
	21			21	
(Cycle repeats)	22			22	
2.6 cycles/year	23	Wean (Cycle repeats) 2.26 cycles/year	Wean 2.26 cycles/year	23	
				24	
				25	
				26	Wean (Cycle repeats) 2.0 cycles/year
Herd av = 2.3 breeding cycles (or litters)/year			Herd av = 2.1 breeding cycles (or litters)/year		

III. CALCULATIONS FOR BALANCED HOG PRODUCTION SYSTEMS

Many swine producers are now integrating all the stages of production outlined in Table 4 within one business operation, or within two businesses linked by a contract. This allows a 'closed herd' policy that reduces the risk of introducing new diseases, and gives good managers the maximum potential for efficient production. It is not necessary to have all housing stages (from breeding through to finishing) on the same farm. But it is important to size all the housing units in correct relation to each other. The following is a method of calculating required numbers of the various specialized pens in each unit to make up a balanced hog production system (Ref. 5).

For illustration, these calculations are all based on a 100-sow breeding herd; this implies 100 active breeding females, plus extra pigs that are also housed in the breeder barn. A typical 100-sow herd would be made up approximately as follows:

100 breeding females (sows and bred gilts)
15 open gilts
5 sows to be replaced
6 boars

126 total animals

SIZING THE BREEDING-GESTATION UNIT

It is not necessary to have places for all 100 breeding females in the breeding-gestation unit at one time since part of the sow group would be housed in the farrowing-nursing barn. Provide breeding-gestation space for about 85 breeding females, or in other words 85% of the breeding herd. In addition, it is customary to provide space in the breeding-gestation unit for the extra animals required to maintain 100 active breeding females. These extras include boars, open gilts and a few sows who have not yet been identified as poor breeders.

SIZING THE ONE-ROOM CONTINUOUS FARROWING UNIT

This system uses a single farrowing area through which all sows are farrowed in sequence. As soon as each pen becomes available, it is cleaned in preparation to receive the next sow about a week before she is due to farrow.

One-room continuous farrowing never permits complete sanitation of the farrowing barn, although careful managers can fill farrowing pens in order starting at one end of the row of pens, to reduce cross-contamination. It is possible to group farrow through a single farrowing room by interrupting the breeding at regular intervals, but this practice reduces the reproduction rate of a herd, increases the number of farrowing pens required, and makes herd management more complicated.

With one-room continuous farrowing, the number of farrowing pens depends on the number of litters to be farrowed per year (no. of sows × breeding cycles/year), as well as the pen cycle time (see Table 5).

Pen cycle time refers to the average time for one complete farrowing-nursing cycle, including weanling time (if required), clean-up time, and filling (or prenatal) time. Table 6 shows three typical farrowing pen cycles suitable for one-room continuous farrowing. Note that all pen cycles include the very important clean-up week for cleaning, disinfecting and drying the pens. See Farrowing Pens (pages 16 to 20) for pen details suitable for these various pen cycles.

Calculate the required number of farrowing pens as follows:

$$\text{Farrowing pens} = (\text{sows}) \times (\text{litters/yr}) \times \frac{(\text{wks/pen cycle})}{(52 \text{ wks/yr})}$$

For example, with the 5-week pen cycle, the number of farrowing pens is:

$$100 \text{ sows} \times 2.3 \frac{\text{litters}}{\text{year}} \times \frac{5}{52} = 22.1 \text{ pens (use 24 pens)}$$

A second example shows the increase in the number of farrowing pens needed for the 12-week farrowing pen cycle with late weaning. For 100 sows, the minimum number of farrowing pens would be:

$$100 \times 2.1 \frac{\text{litters}}{\text{year}} \times \frac{12}{52} = 48.4 \text{ pens (use 50 pens)}$$

SIZING THE MULTIPLE-ROOM FARROWING UNIT

Multiple-room farrowing is a proven method of farrowing pen management designed for better disease and parasite control in the critical first weeks of the pig's lifetime. This method is to bring the sows and litters through the farrowing-nursing stages in groups, and permits complete clean-up of a farrowing room at the end of each pen cycle. This is particularly suited to larger herds (over 100 sows). Here management becomes most critical, and the separated farrowing rooms are each large enough to be practical to build and ventilate.

To make multiple-room farrowing function without a delay in re-breeding, farrowing space is divided into three or four separate rooms, isolated from each other as well as from outside contamination. At clean-up time, each farrowing area in rotation is cleaned, sterilized, then closed and locked for a drying period, and to prevent recontamination before the next sows are washed and brought in for farrowing. See Figure 2 for a typical four-room group farrowing arrangement.

TABLE 6. FARROWING PEN CYCLES FOR ONE-ROOM CONTINUOUS FARROWING

	5-week pen cycle	8-week pen cycle		12-week pen cycle	
Stage	Early wean	Early wean	Late wean	Early wean	Late wean
Filling	1 week	1 week	1 week	1 week	1 week
Nursing	3 weeks	3 weeks	6 weeks	3 weeks	6 weeks
Weanling	0	3 weeks	0	7 weeks	4 weeks
Clean-up	1 week	1 week	1 week	1 week	1 week

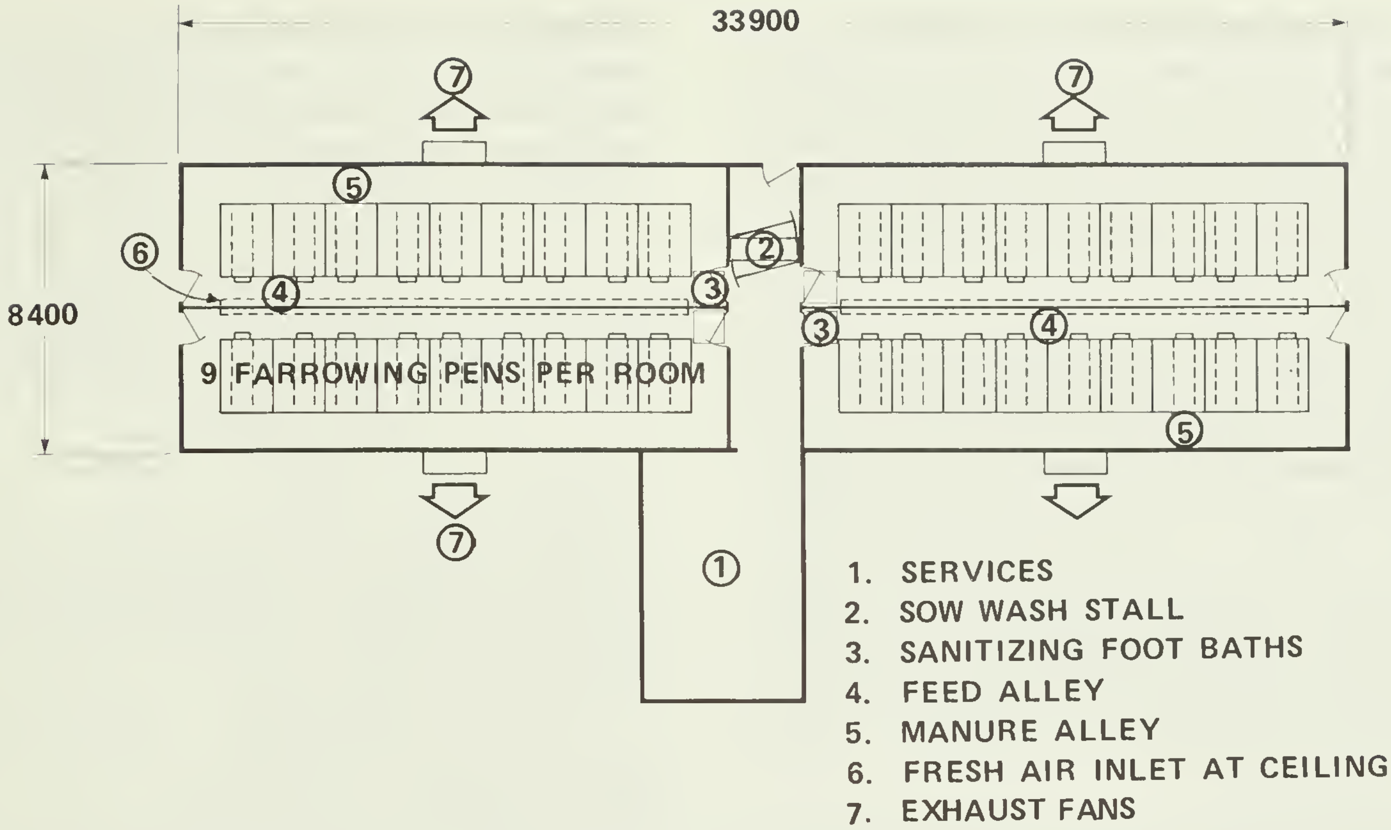


Figure 2. Four-room group farrowing barn for 100-sow herd, short hall plan.

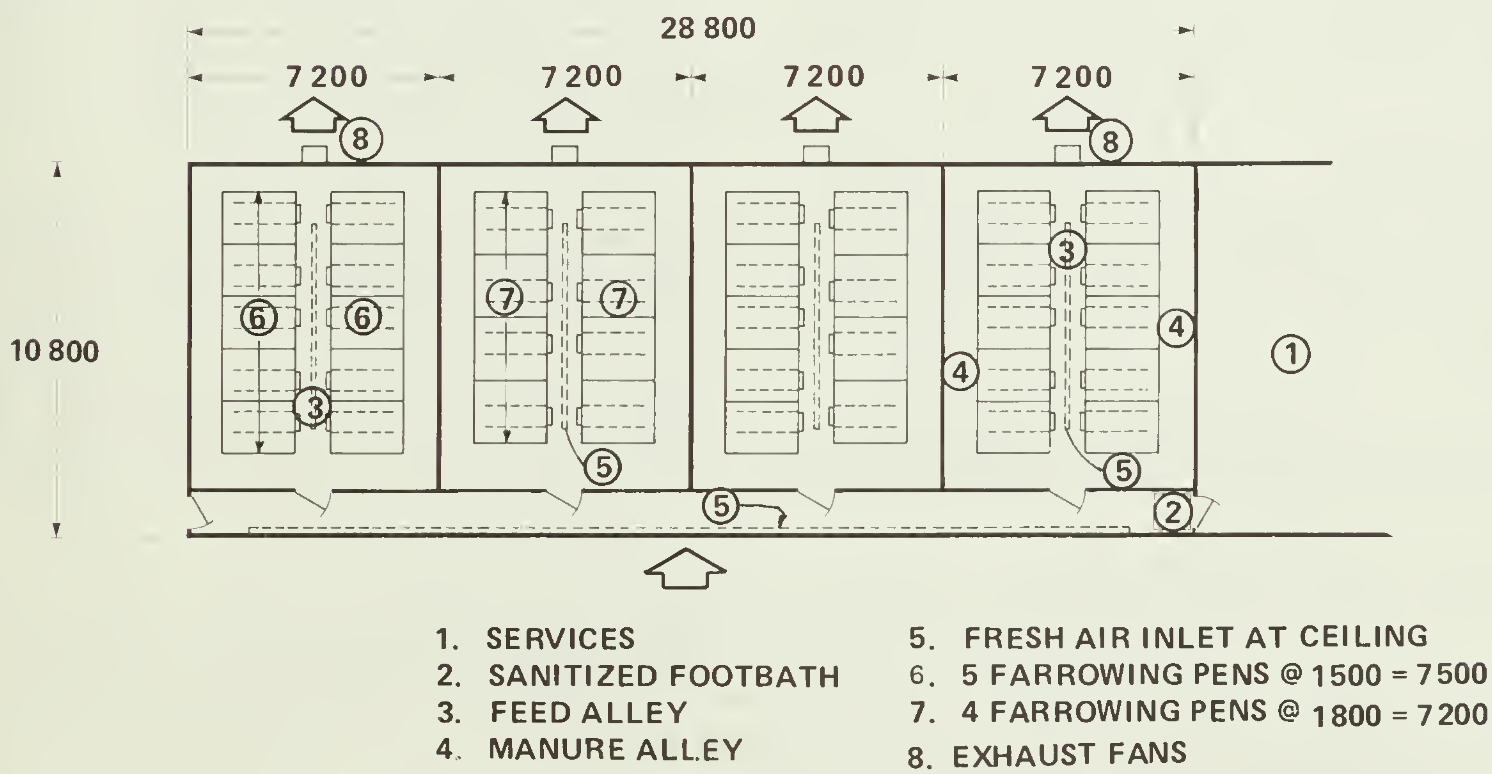


Figure 3. Four-room group farrowing barn for 100-sow herd, long hall plan.

One practical method of operating a group farrowing system is described as follows: Sows and gilts are bred as rapidly as possible when they come into natural heat. The manager arranges record cards for females confirmed pregnant, in the order in which they are expected to farrow. In this order, and about a week before farrowing, sows are washed and moved into a clean farrowing room until all pens in that room are occupied. As soon as one room is full, the next sows start going into the next room, and so on. One week before the first room is to be reoccupied, all sows and weaned pigs are moved out to allow clean-up time.

This revolving system depends on the effective size of the breeding herd being balanced to the farrowing space, considering also the room cycle time. If the manager starts to run out of time for clean-up of the farrowing rooms, this indicates that he has more breeding females than the system needs, and he can cull.

To explain this another way, assume that four farrowing rooms are planned to be operated on a 12-week room cycle. Theoretically this allows 3 weeks to fill each room in sequence. If, however, the rooms are filling in less than 3 weeks (say 2 1/2), the room cycle could be adjusted to repeat in something less than 12 weeks total (10 weeks). Thus the manager has three choices; losing clean-up time (not desirable), culling sows, or reducing room cycle time by taking weaned pigs out of farrowing rooms at an earlier age. Culling the poorer sows is the best choice.

If, on the other hand, the farrowings are not keeping up to available space, this will be indicated by a farrowing room not yet full at the end of the time allowed for filling (3 weeks, in this example). If this occurs, the next sow group must start filling room 2 even though room 1 is not yet full, otherwise the late sows will farrow too late in the first room and the valuable clean-up time will be lost. The manager in this situation should either increase the breeding herd or improve the conception rate.

Table 7 shows five of many farrowing room cycles suitable for four-room farrowing. This table differs from Table 6 in that each filling time is increased to a quarter of the corresponding room cycle time. This is necessary to be sure that sows due to farrow will always find pens available.

For 100 sows, early weaning and 6-week farrowing room cycle the number of farrowing pens is:

$$100 \text{ sows} \times 2.3 \frac{\text{litters}}{\text{year}} \times \frac{6 \text{ wks/room cycle}}{52 \text{ wks/year}} = 26.5 \text{ pens}$$

(use 4 × 7 = 28 pens)

The 28 pens required here are four more than the 24 pens calculated above for one-room farrowing. Other extra costs for multiple-room farrowing include four separate ventilation and heating systems, and of course extra doors and walls.

For 100 sows, late weaning and 12-week farrowing room cycle, the number of farrowing pens is:

$$100 \text{ sows} \times 2.1 \frac{\text{litters}}{\text{year}} \times \frac{12 \text{ wks/room cycle}}{52 \text{ weeks/year}} = 48.4 \text{ pens}$$

(use 4 × 13 = 52 pens)

Three-room group farrowing systems also work well since the three rooms fit logically into the natural 3-week ovulation cycle of the sows. It is more difficult however to arrange three rooms symmetrically to minimize wasted traffic space.

SIZING THE WEANLING UNIT

Some extended farrowing room cycles (such as the 12-week cycles in Tables 5 and 6) provide enough time to grow piglets to 8 or 10 weeks of age (18 to 25 kg weight) before moving them out of the farrowing-nursing pens. This requires dual-purpose farrowing-nursing pens designed for easy manure removal and having enough unobstructed space for a large litter of weanlings. This plan eliminates the special intermediate weanling housing and also eliminates one growth pause usually suffered by pigs adjusting to new surroundings.

The 12-week farrowing pen cycle without special weanling housing is popular with small producers. With large operations, however, a special weanling area in the system can reduce costs, because it allows a considerable reduction in the size of the more-expensive farrowing unit. Total farrowing-nursing-weanling space in a production system is also reduced because the weanling pens can be sized to fit the special needs of the weanling pigs.

Many operators combine and re-sort litters at weanling stage into groups of 20 barrows or 20 gilts. Table 4 indicates 0.2 to 0.3 m² of pen area per weanling pig,

TABLE 7. FARROWING ROOM CYCLES FOR FOUR-ROOM FARROWING

	6-week room cycle	8-week room cycle		12-week room cycle	
Stage	Early wean	Early wean	Late wean	Early wean	Late wean
Filling	1.5 weeks	2 weeks	2 weeks	3 weeks	3 weeks
Nursing	3.5 weeks	3 weeks	5 weeks	3 weeks	6 weeks
Weanling	0	2 weeks	0	5 weeks	2 weeks
Clean-up	1 week	1 week	1 week	1 week	1 week

therefore 20 weanlings × 0.25 m^2 = 5 m^2 pen area. This requires pens about 1.2 m × 4.2 m = 5.04 m^2, or 1.5 m × 3.3 m = 4.95 m^2. This shows that specialized weanling housing saves barn space, since a single litter left in the farrowing pen after weaning would require almost twice as much barn space per pig.

Assuming a 100-sow breeding herd averages eight pigs per litter, annual weanling pig production should be:

$$100 \text{ sows} \times 2.3 \frac{\text{litters}}{\text{year}} \times 8 \frac{\text{weanlings}}{\text{litter}} = 1840 \frac{\text{weanlings}}{\text{year}}$$

The number of weanling pens for pigs 3 to 10 weeks old (7 weeks weanling period), at 20 weanling pigs per pen is:

$$\frac{1840 \text{ weanlings/year}}{20 \text{ weanlings/pen}} \times \frac{7 \text{ wks weanling period}}{52 \text{ wks/year}} = 12.9$$

(provide 14 pens)

SIZING THE GROWING-FINISHING UNIT

The most popular pen size for growing and finishing pigs is 1.5 × 4.8 m. This size is suitable for up to 20 growers at 0.36 m^2/pig, or 10 finishers at 0.72 m^2/pig. This allows the herdsman to move groups of 20 weanlings into the larger growing pens without introducing any new 'strangers' into the group, a practice which eliminates one source of stress and fighting. At 0.36 m^2/pig these growers soon become crowded; as soon as pens are available, each group is split into 2 groups of 10, giving 0.72 m^2/pig. Since growing and finishing pens are identical, this makes a flexible arrangement that keeps the growing-finishing barn almost fully occupied and yet allows some variation in pig population. A good basis for calculating required pen space is 10 to 14 weeks of age in growing, and 14 to 24 weeks of age in finishing. Figure 1 implies that pigs can reach market weight in less than 23 weeks, but this is an ideal, not a practical average.

Following the example calculations above, and the growth curve shown in Figure 1, page 7, the numbers of growing and finishing pens to match the 100-sow herd are as in the example below.

This example would require a growing-finishing barn 10.8 m wide by (22 × 1.5) + 0.6 = 33.6 m long. The 0.6 m added length allows for endwalls plus enough added length to bring the total length to a multiple of 1.2 m for convenient metric construction. An additional area for services and pig-handling is usually attached to one end, or to the mid-length if the barn is long enough to be divided in half.

$$\frac{1840 \text{ growers/year}}{20 \text{ growers/pen}} \times \frac{4 \text{ wks/growing period}}{52 \text{ wks/year}} = 7.1 \text{ growing pens}$$

$$\frac{1840 \text{ finishers/year}}{10 \text{ finishers/pen}} \times \frac{10 \text{ wks/finishing period}}{52 \text{ wks/year}} = 35.4 \text{ finishing pens}$$

Total = 42.5 pens
(provide 44 pens, for an even number)

IV. PENS FOR CONFINEMENT SWINE PRODUCTION SYSTEMS

BREEDING AND GESTATION

Pork production begins in the breeding-gestation housing, and the management of this part of the production unit is the key to profitability for the entire enterprise. Producers should aim for 85% conception rate and annual production of 18 weaned piglets per sow. There are important management factors that can improve the conception rate, as follows:

Light, 15 to 18 hours per day, has been shown to optimize conception rate. Windows in a specialized breeding area can provide this day-length in the early summer, but in other seasons the natural day will be too short. And in winter, ordinary windows will waste more energy than they can save during the brief spring-summer period when they provide enough daylight. The best alternative is therefore to eliminate windows and use electric lighting with time-clock controls.

Breeding gilts and sows should be penned in compatible groups in a specilized breeding area where boar pens are alternated with female pens. This arrangement encourages the normal social contacts which can improve breeding performance.

Boars should be rotated weekly about the breeding area. This adds some stimulating social variety.

Pen partitions between boars and breeding females should be vertical open grating to maximize inter-pen communication. Horizontal dividers and high, solid partitions such as concrete or planking are not recommended.

Foot and leg problems, especially with boars, can be controlled by providing dry, non-skid concrete pen floors. Walk the boars regularly through a shallow footbath in a passage floor. Use 10% copper sulphate or formalin solution in the footbath.

Individual controlled mating is preferred over group breeding. Where two or more boars are penned together, use a 'private' breeding pen at least 2.1 m wide, with a non-skid floor surface (textured concrete, or sand). Breeding twice each heat period improves conception rate.

After breeding, sows must be limit-fed to control excessive weight gain. Restricted feeding stalls 400 to 450 mm wide can be used, at the front of the gestation pens (see Figure 4). Since these feeding stalls must be narrow enough to admit only one sow standing, they are too narrow to serve also as sleeping stalls. In new facilities this extra pen space is costly, therefore rows of pen stalls (Figure 6), or tie stalls (Figure 7), preferably facing head-to-head, are being used more and more.

Pregnancy-check the bred females regularly. One way to do this is to let a boar walk in front of the sow pens or stalls each day.

Figure 5 shows a popular breeding-gestation pen for housing a boar, 5 or 6 gilts, or up to 5 sows. First-litter gilts especially should be group-housed during gestation in pens like this, rather than individual pen stalls or tie stalls. Floor feeding (without bedding) works quite well for pregnant females. However, sows and gilts housed for breeding are unsettled and cranky, and the floors are too messy. Breeding pens therefore should have feed hoppers secured to the front gate as shown.

Breeder herds produce a lot of manure; therefore another important requirement for breeding-gestation housing is an easy method of cleaning pens and removing waste so the manager will have enough time for the critical tasks of checking and moving pigs, breeding, and keeping records. Figure 5 shows two suitable manure systems.

Individual pen stalls (see Figure 6) are preferred by some swine breeders for more exact control of feed intake. Pen stalls prevent feeding competition and fighting during breeding and gestation periods. Some operators use pen stalls for feeding small groups of sows in rotation (cafeteria feeding); this reduces costs but requires more labor to move the sows. Pen stalls reduce the available methods of detecting heat and may therefore be unsuitable for confining open sows and gilts.

Individual tie stalls were developed to simplify individual confinement hardware. With a sow tied by the neck or shoulder, length and height of stall dividers can

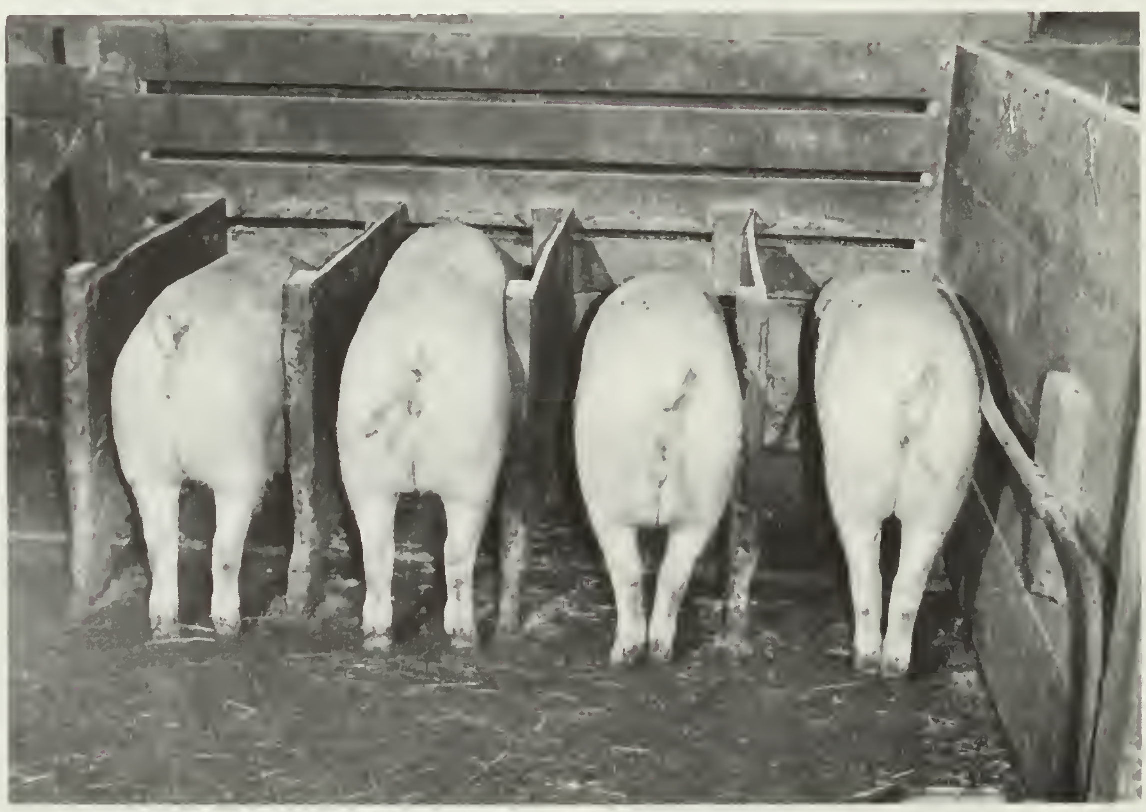


Figure 4. Restricted feeding stalls for gestation sow pens.

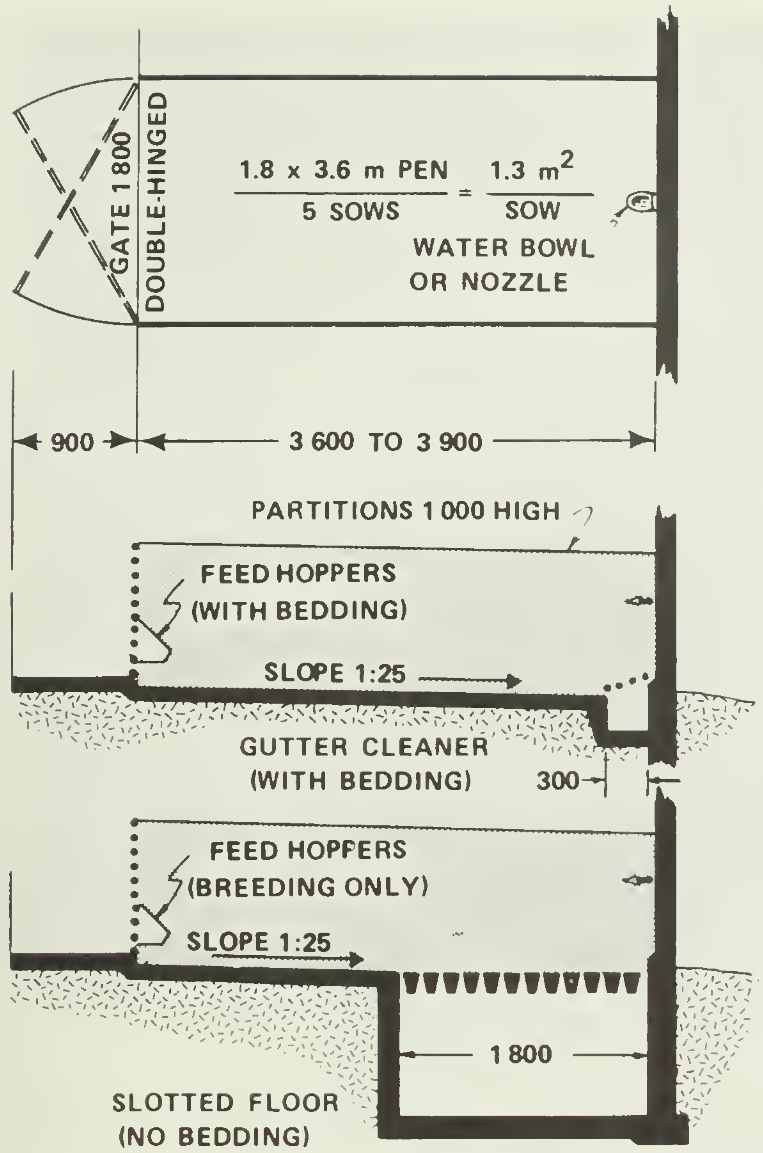


Figure 5. Group breeding-gestation pen with two alternate manure systems.

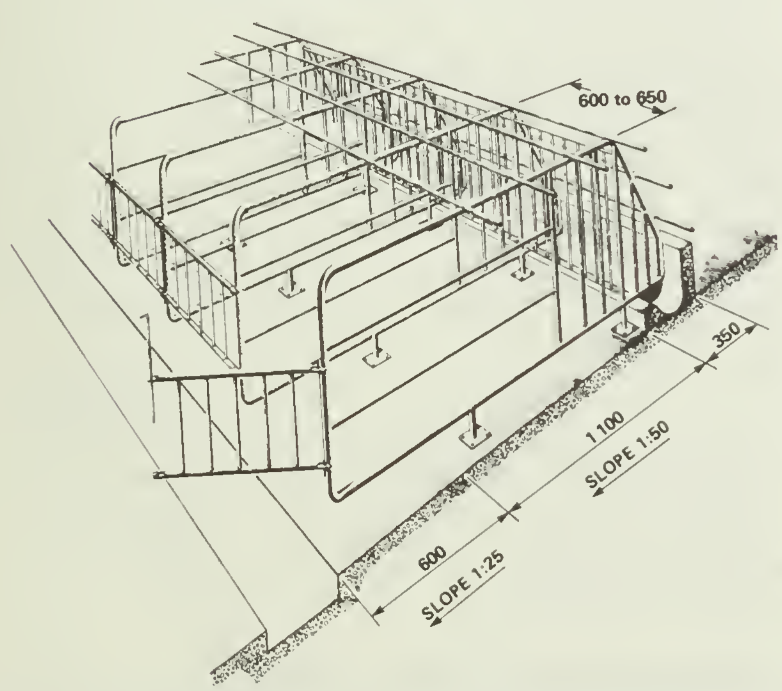


Figure 6. Individual sow pen stall for breeding-gestation housing.

be reduced and no rear gate is needed. First attempts to tie sows by a soft strap neck collar were not satisfactory; the neck and head structure of the sow made it necessary to overtighten the collar. Another tie system uses a strap around the chest area, just behind the shoulders. This requires a floor anchor located farther back in the stall than the neck types. Strong buckles and nylon webbing from automobile seat belts work best (see Figure 7).

Feeding and watering systems are the same for both pen stalls and tie stalls. Manufacturers supply separate feed and water bowls as part of the pen stall or tie stall hardware, however these items are not ncessary if a suitable trough is built into the concrete floor. This trough should be smooth and hard and without sharp inside corners, so that the sows can keep it clean. One good idea is to use a trough liner of 250 or 300 mm glazed clay tile, cut in half. A single continuous trough set level in the concrete serves a row of stalls. Supply fresh water to the trough at one point by means of a guarded float valve, and a shut-off valve. Adjust the float valve to maintain water about 40 mm deep in the trough.

To feed, place a measured scoop of dry ration in front of each sow. Water remaining in the trough soaks the dry feed, helping to reduce dusting and feed wastage.

With pen stalls (Figure 6) or tie stalls (Figures 7, 8), some bedding may be used provided the manure handling system is compatible. The manure may be scraped from the gutter with a shovel, or a mechanical gutter cleaner may be installed if the gutter can be laid out in a simple rectangular circuit. A two-slope stall floor helps provide better drainage to the gutter at the rear of the stall; too much floor slope can cause prolapse of the uterus. A slotted concrete floor at the rear of the stalls (Figure 8B) is a labor-saving alternative for a liquid manure system without bedding. A further advantage of slotted floors is that no slope is required at the rear of the stalls. Tie stalls and pen stalls are made 600 to 700 mm wide including pipe-frame stall dividers.

Tie stalls are usually not satisfactory for gilts since they have not yet experienced farrowing and the close confinement associated with it. A few sows may also resist the tie stall, and the struggling may cause soreness. For these reasons, the best plan for a breeding-gestation unit includes both stalls and group pens. See Figure 9 for one possible layout, suitable for up to 100 sows.

FARROWING PENS

Requirements for farrowing pens include confinement, feed and water for the sow. The newborn pigs need extra warmth, as well as protection from smothering by the sow. And both mother and piglets need dry comfortable lying areas, which means floors must be sloped or slotted so that liquids never accumulate within the pen.

Figure 7. Sows in gestation tie stalls with belly-strap ties.

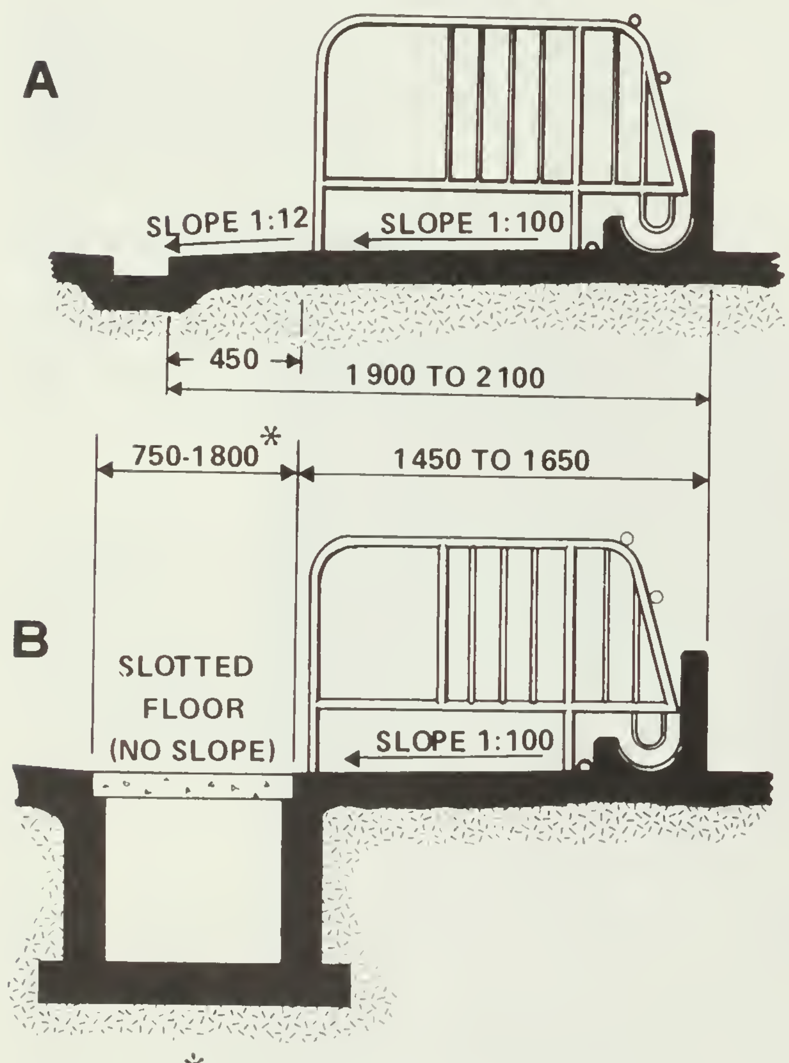


Figure 8. Sow tie stalls with solid or slotted floors.

All good farrowing pen designs include a heated 'creep' area to encourage the piglets to leave the sow after nursing and go to a much warmer environment than that required for the sow. The creep area usually has an insulated concrete floor (see Chapter VI). Creep heat is usually supplied by heat lamps (see Figure 11) or electric radiant heaters suspended from ceiling hooks and ceiling-mounted electrical outlets. Since the introduction of convenient and safer quartz-tube electric radiant heaters (see Figure 49), the other heating methods are less popular.

There are too many variations in farrowing pen design for a complete description here, but pens may be grouped into side creep and front creep types, according to the location of the heated creep area in relation to the sow.

Side creep farrowing pens are shown in Figures 12 and 13. In Figure 13, two styles of farrowing crates are shown with three methods of handling manure, and other combinations of these options are possible too. Figures 13 (A and B) show a standard farrowing crate of commercial manufacture to confine the sow at front, sides, rear and top. Crates of this type are generally adjusted at the rear for sows of various lengths; the adjustment may be provided by short pipes or lengths of chain pinned or hooked at several positions across the

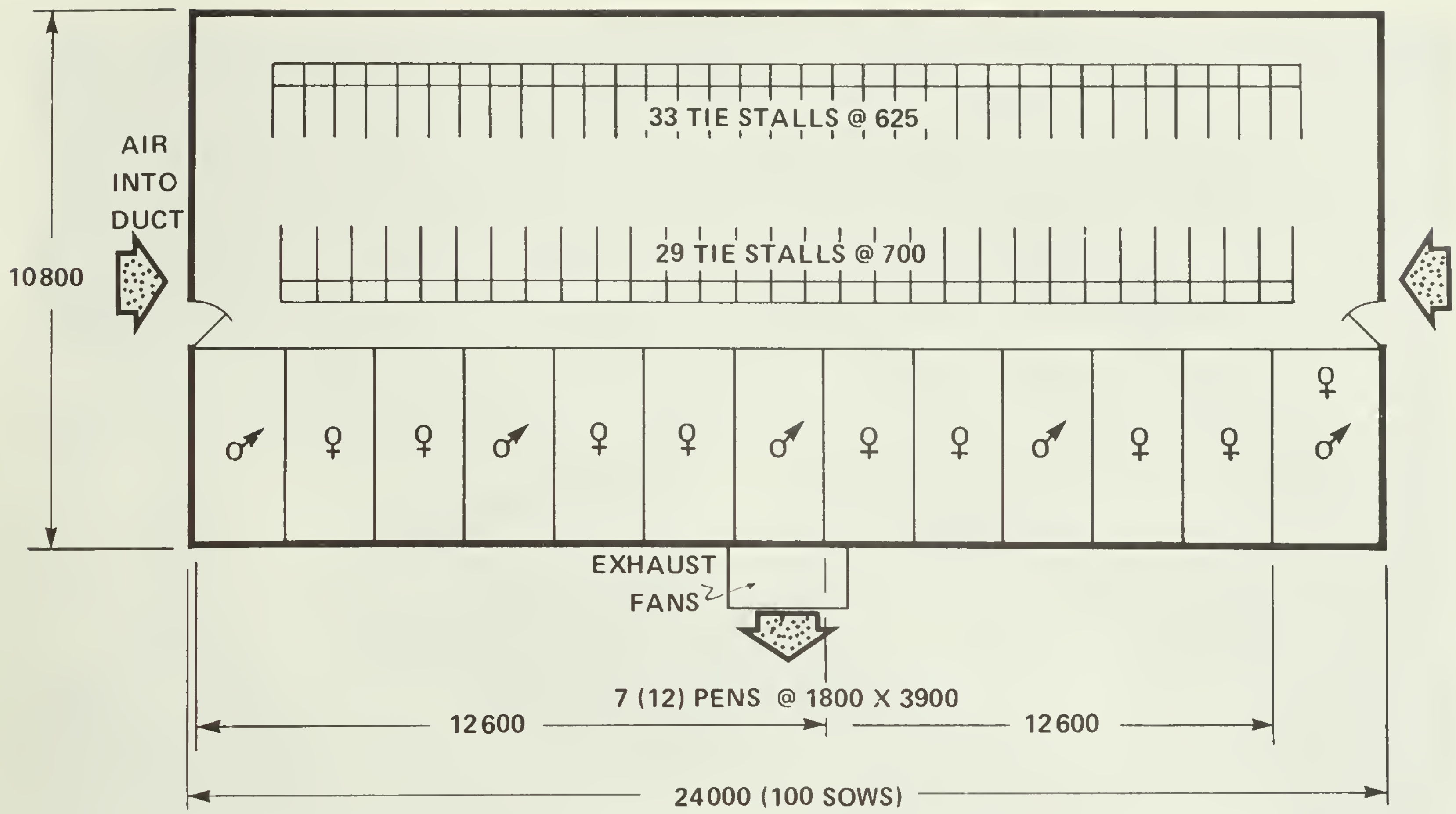


Figure 9. Breeding-gestation barn with gestation tie stalls for sows and pens, for breeding, gilts or boar.

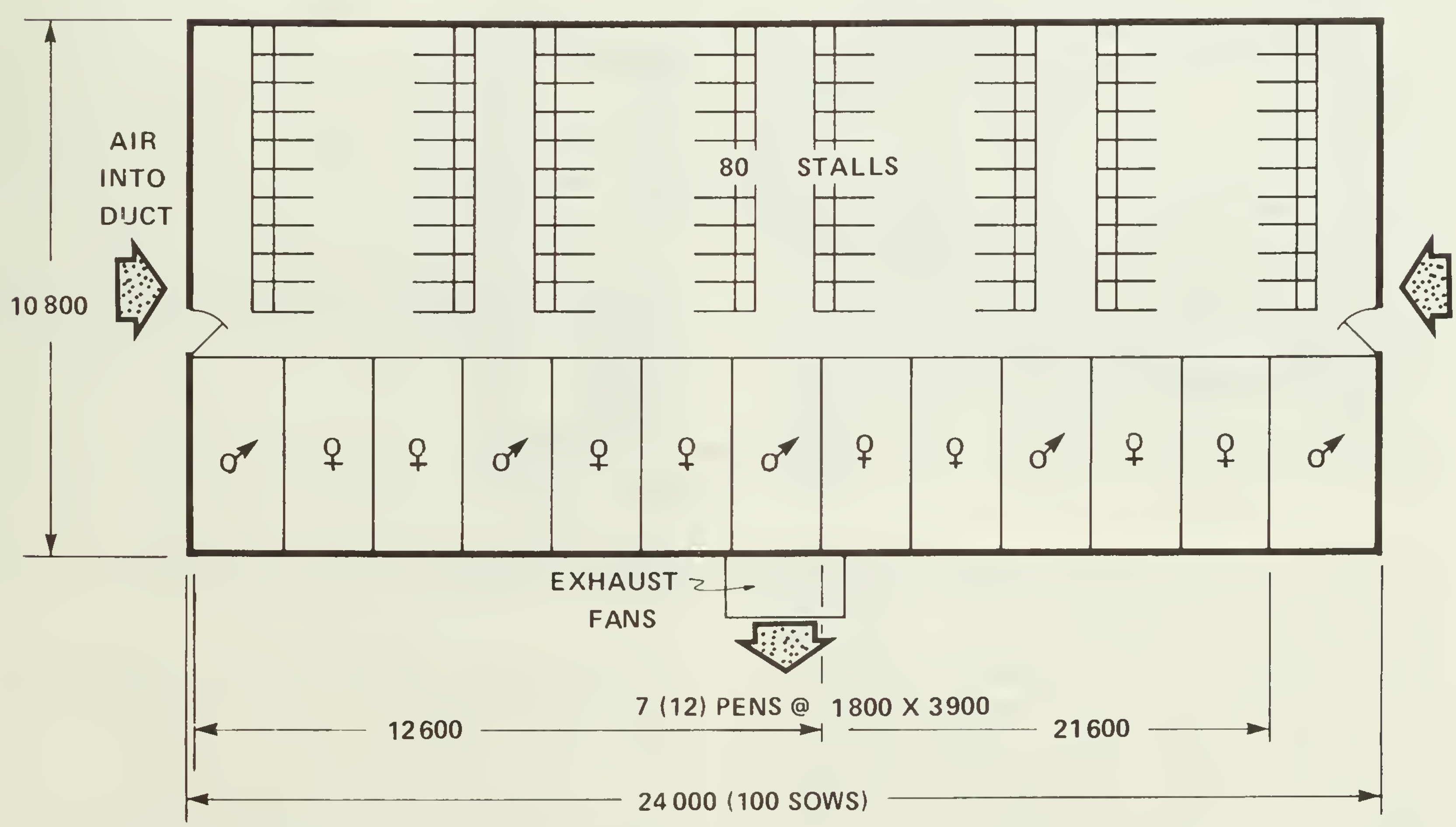


Figure 10. Breeding-gestation barn with tie or pen stalls for sows, and pens for gilts or boar.

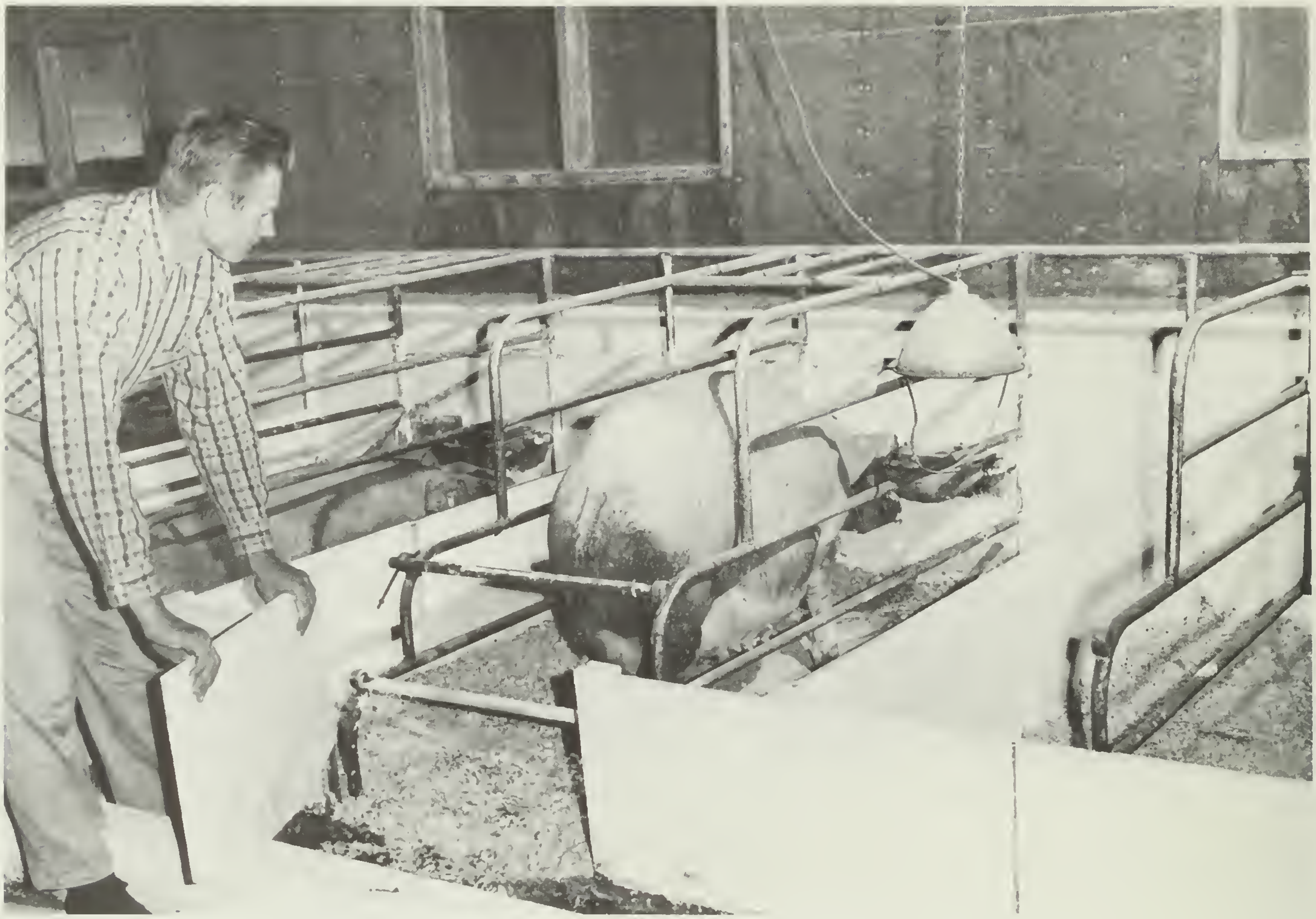


Figure 11. Side-creep farrowing pen with a protected heat lamp over the creep area.

rear of the crate. Or to simplify moving sows, some manufacturers clamp the adjustment device to the rear gate.

Figure 13C shows a farrowing crate adjustable at the front instead of at the rear. A small gate hangs pivoted at the sow's forehead; this gate gently pushes the sow to the rear of the stall except when she reaches forward to feed or drink. This results in manure being dropped in a smaller area, so that the required area of slotted floor is reduced. Fore-and-aft adjustment of the forehead gate hinge-pins can accommodate sows of various sizes.

Farrowing pens with side creeps fit into a floor area about 1.5 to 1.8 m wide by 2.1 m long. Pens 1.5 m wide are minimal and work best for early weaning at 3 to 4 weeks of age. Creeps of unequal width (300 mm one side, 600 mm other side) can be used to get enough space for the heated creep with insulated floor at one side of each pen. Alternate the wider heated creeps right and left so that the heated areas are side-by-side; this makes better use of the heat lamps or other creep heating and simplifies wiring to electrical outlets on the ceiling. The cantilever slotted floor (Figures 12B, 13B) was developed to combine frequent manure removal with the sanitary advantages of slotted floors. A special offset scraper blade pivoted for right- or left- hand operation on a handle made of thinwall pipe is used to push manure out of the farrowing barn. Some operators minimize work and odors by damming the liquids in the gutter for a day or two, then cleaning out. The removable slotted floor unit is supported on angles bolted through the extended creep partitions and/or steel bars embedded into the concrete stall floor. Slotted floor materials may include galvanized steel channels with punched slots, grids of reinforced concrete, woven wire, plastic-coated expanded metal, or slats of aluminum, stainless steel and fiberglass. See Canada Plan Service plan 3801 for more details.

If a liquid manure system is used (no bedding), the concrete slotted floor with deep flushing gutter can be used (see Figure 13C).

Water for the sow may be supplied by hog drinker bowl or drinker nozzle; the best location for the drinker nozzle is directly over the feed hopper. Piglets should be en-

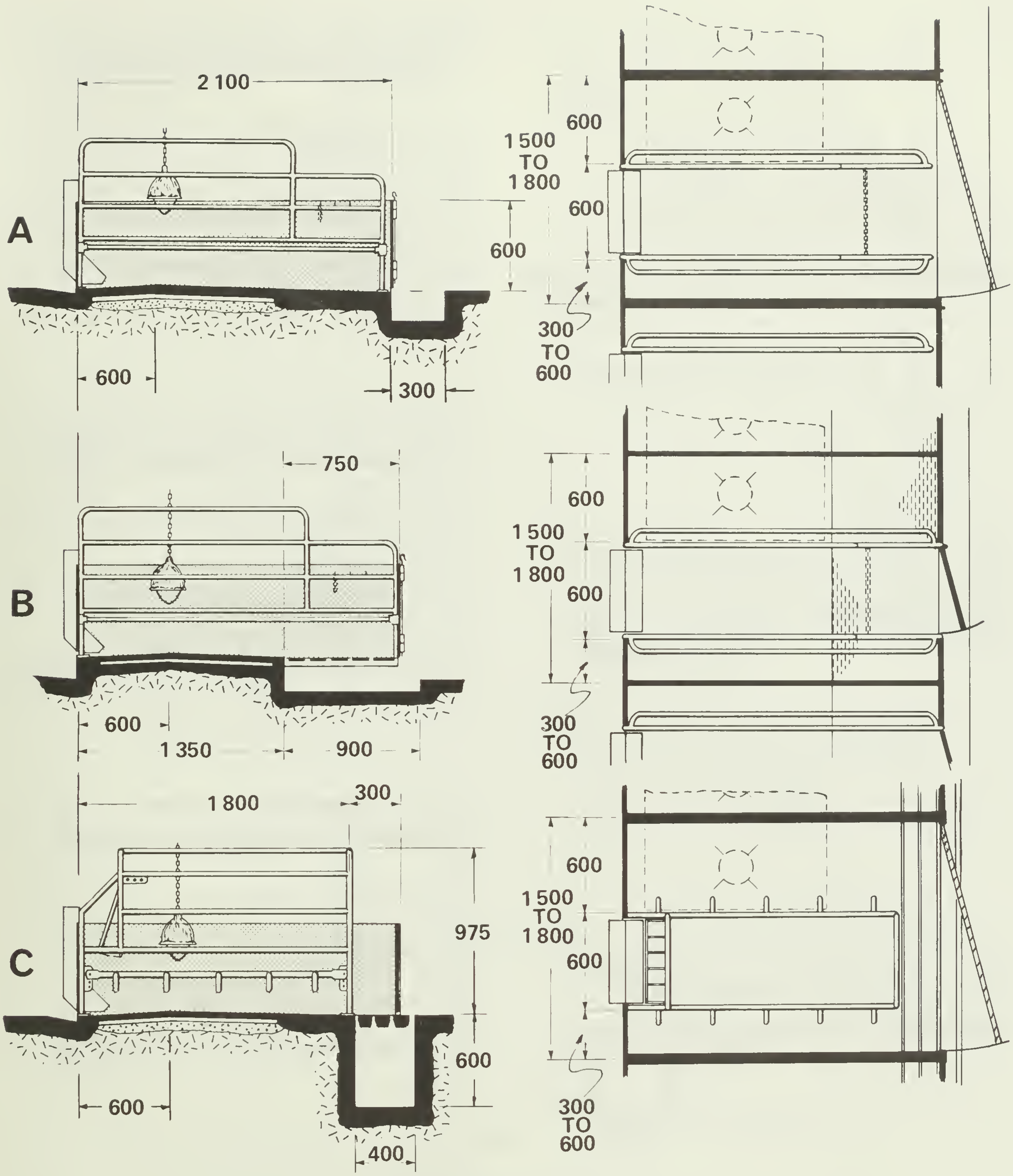


Figure 12. Farrowing pens with side creeps.

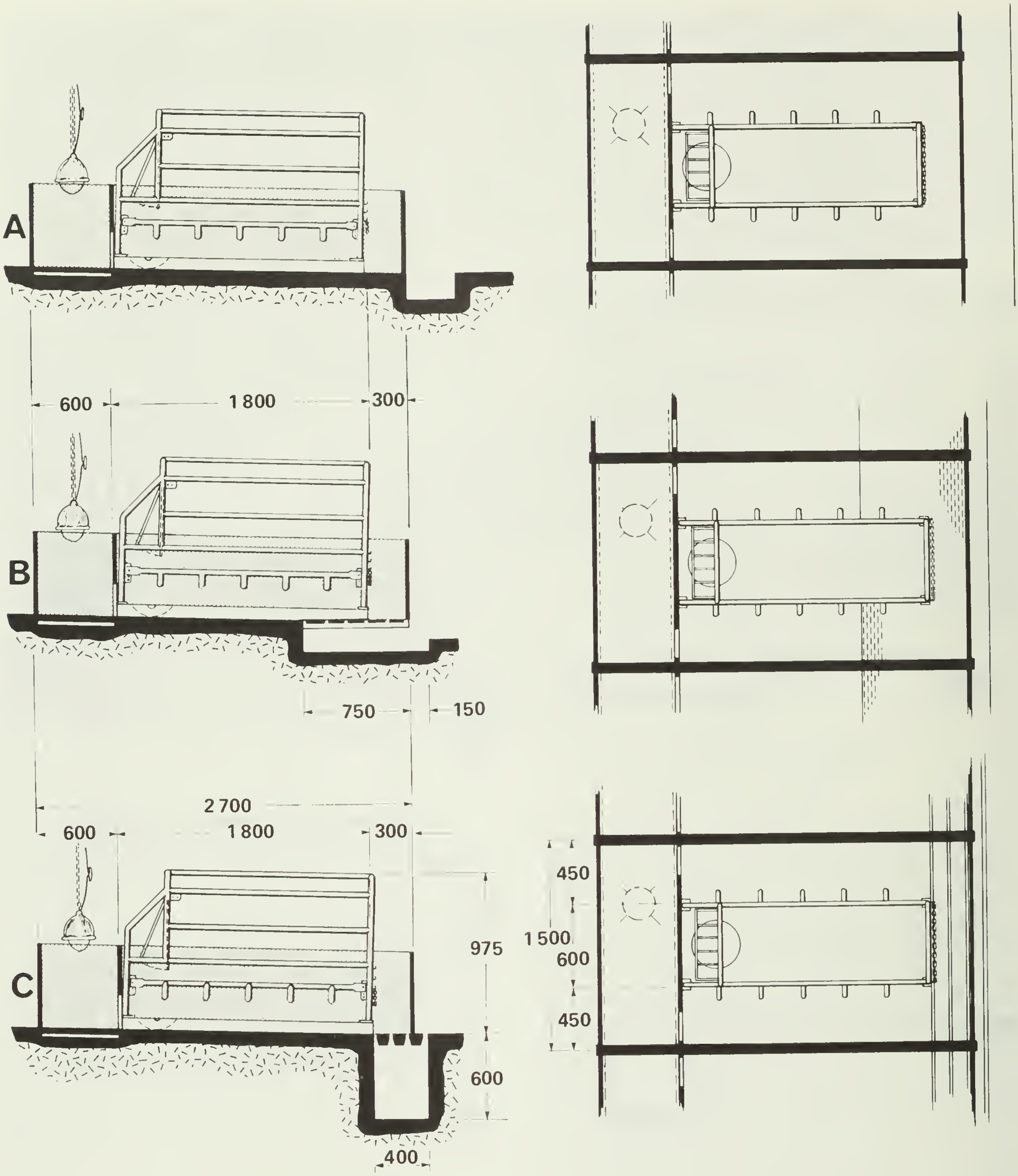


Figure 13. Farrowing pens with front creeps.

couraged to feed and drink early, by use of a front corner creep feeder and special piglet drinkers. The piglet drinkers should be near the rear gutter although water supply piping is easier to connect at the front.

Front creep farrowing pens are shown in three styles in Figure 13. These styles are grouped together to illustrate their common space requirement of approximately 1.5 × 2.7 m. Front creep pens require more

floor space than side creep pens; the front creeps however make it easier to raise the creep temperature up to the comfort level for newborn pigs without overheating the sow.

With front creeps, it is not as easy to have a front drainage gutter as with side creeps, so floors are sloped one way only, to the rear. Thus water spilled by the sow would make her sleeping area wet and dirty. This can be solved by adding a raised concrete pad under the sow. With the sow lying 'high and dry' the udder stays cleaner, and even newborn piglets nurse readily. Occasionally a weak liter may need a plank laid beside the concrete platform for the first day or two.

Both front-creep and side-creep farrowing pens as shown here positively commit the farrowing pen area to farrowing only. The small producer (under 20 sows) may prefer a more versatile pen that can serve for boar, gestation, farrowing, weanling, or growing-finishing housing. One way to do this is to make all pens about 1.5 X 3.6 m, then convert any such pen to farrowing by adding a portable farrowing crate. Bolt a commercial steel farrowing crate (such as Figure 12A or 13C) to a floor panel of doubled 18 mm plywood cut slightly larger than the length and width of the crate. This makes a portable unit that can be put into the pen or lifted out as required. The weight of the sow on the plywood floor prevents any movement of the stall.

WEANLING PENS

As outlined before, the weanling pen can be sized to suit about 20 weanlings. A pen 1.2 X 3.6 m as shown in Figure 14 thus provides 0.2 m²/pig.

Weanling pigs may be fed from a feed cart into a self-feeder forming part of the pen partition (see Figure 14A). Alternatively, if no bedding is used, weanlings may be floor fed, usually by feed cart and a calibrated hand scoop. Floor feeding requires less equipment and encourages cleaner pen habits. Automatic mechanical feed meters designed for use in larger growing-finishing units are not usually justifiable in the weanling unit.

Solid pen partitions are recommended by veterinarians for better control of contact diseases, but open pen partitions reduce fighting and spooky pigs. It is essential however to use a pen front gate of steel mesh or similar open material, for good pen ventilation.

Figure 14 shows four optional manure systems. The trend is towards increasing the proportion of slotted floor in weanling pens, with total slotted floors (Figure 14D) the obvious limit. Weanling pigs must be kept especially clean to maintain good health, and slotted floors are the only sure way of maintaining clean weanling pens.

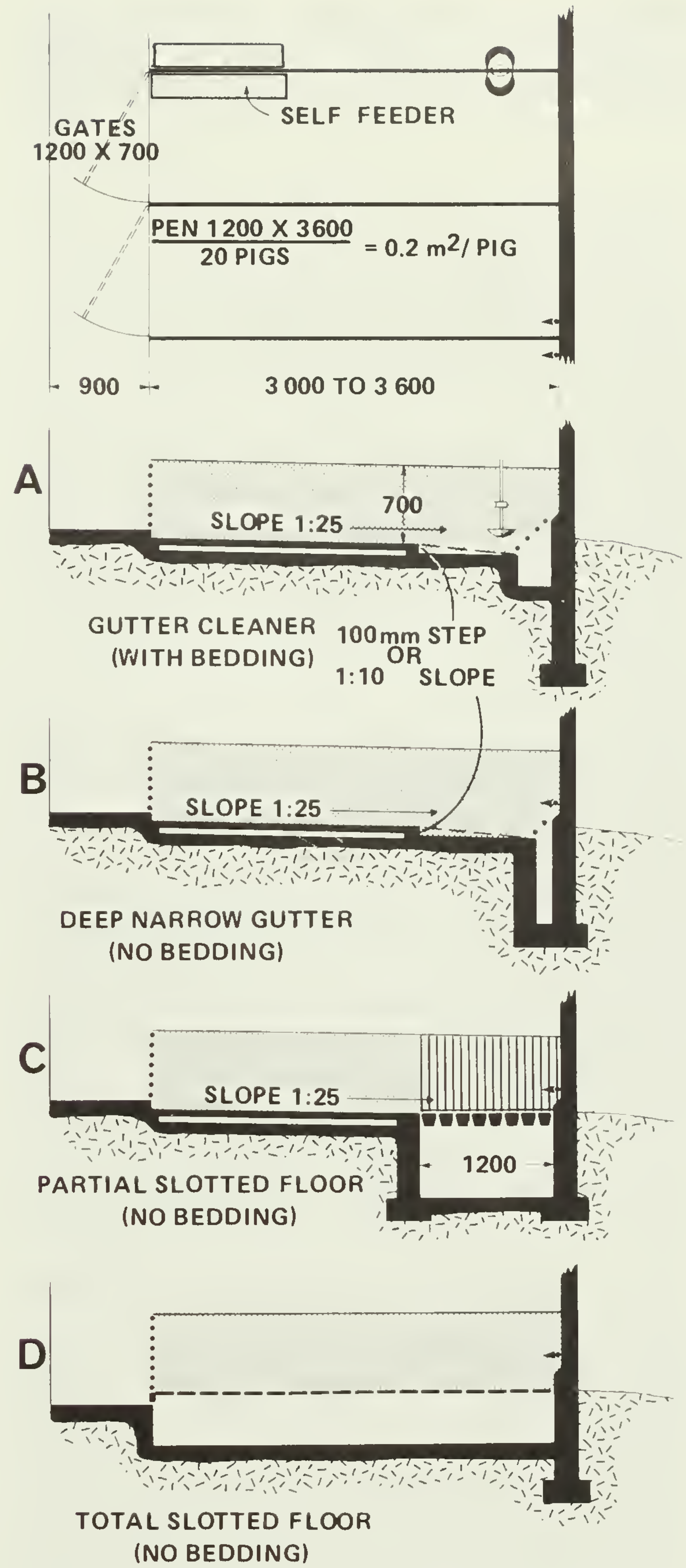


Figure 14. Weanling pens with four alternate manure systems.

A variety of slotted flooring materials is being tried, including galvanized expanded steel mesh, hardwood slats, reinforced concrete grids, and galvanized sheet steel channels with punched holes. The ideal slotted floor is durable, self-cleaning, non-slip for walking, comfortable for lying, and inexpensive. This ideal has not been found, otherwise all pens would now have the same flooring. With total slotted floors, weanling pens

should have a temporary solid floor panel (such as plywood) adjacent to the self-feeder when new weanlings first go in. This can be removed as soon as there is any manure found collecting in it.

Weanling pigs just out of the farrowing creeps require good temperature control (21°C minimum) as well as warm floors. Floors in the sleeping area should be insulated. Supplemental heat is required to maintain temperature in winter. Quartz-tube electric radiant heaters suspended from the ceiling over the sleeping area provide heat where it can give the most comfort to the pigs. This is a simple system to install and adjust but is suitable only for electric heating. As an alternative, electric resistance cable or hot water circulation piping can be installed in the insulated floor slab. For more details, see Chapter VII, Methods of Adding Heat.

GROWING-FINISHING PENS

Pens for the growing and finishing stages of production can be as small as 1.5 × 4.8 m, giving 1.5 × 3.8/20 growers = 0.36 m^2 per growing pig. This space doubles to 0.72 m^2/pig when the group is split into tens for finishing. Other pen sizes may be used of course, but it is very important to maintain the same proportions; pigs in a long narrow pen are more likely to develop clean habits than those in square pens. Slotted floors keep pigs cleaner, but pigs have fewer foot injuries and gain with less feed if only part of the floor is slotted (ref. 6).

Three methods of feeding are shown in Figure 15. The liquid feeder is a commercial type with a continuous trough at floor level; centered over this trough is a zigzag partition to divide two adjacent pens and provide a feeding compartment for each pig, to control competition. Liquified feed is pumped from a central mixing station and dispensed into each double feed trough through a hose and nozzle similar to those at gasoline pumps. The system requires no pen watering device, and it combines well with the slotted floor liquid manure system. The costs of the central mixing station and feed distribution piping are relatively high, so the system is applicable only to very large units.

For restricted feeding, feeding on the floor is the simplest arrangement. For minimum investment use a feed cart and hand scoop. Floor feeding can be mechanized by an automatic feed conveyor supplying a self-dumping feed meter over the front of each pen. Typical problems to consider however are dust, feed wastage, possible spreading of enteric disease and inadequate inspection of the pigs. Pelleted feed helps reduce dust and feed wastage.

Self-feeders can be used if restricted feeding is not a re-

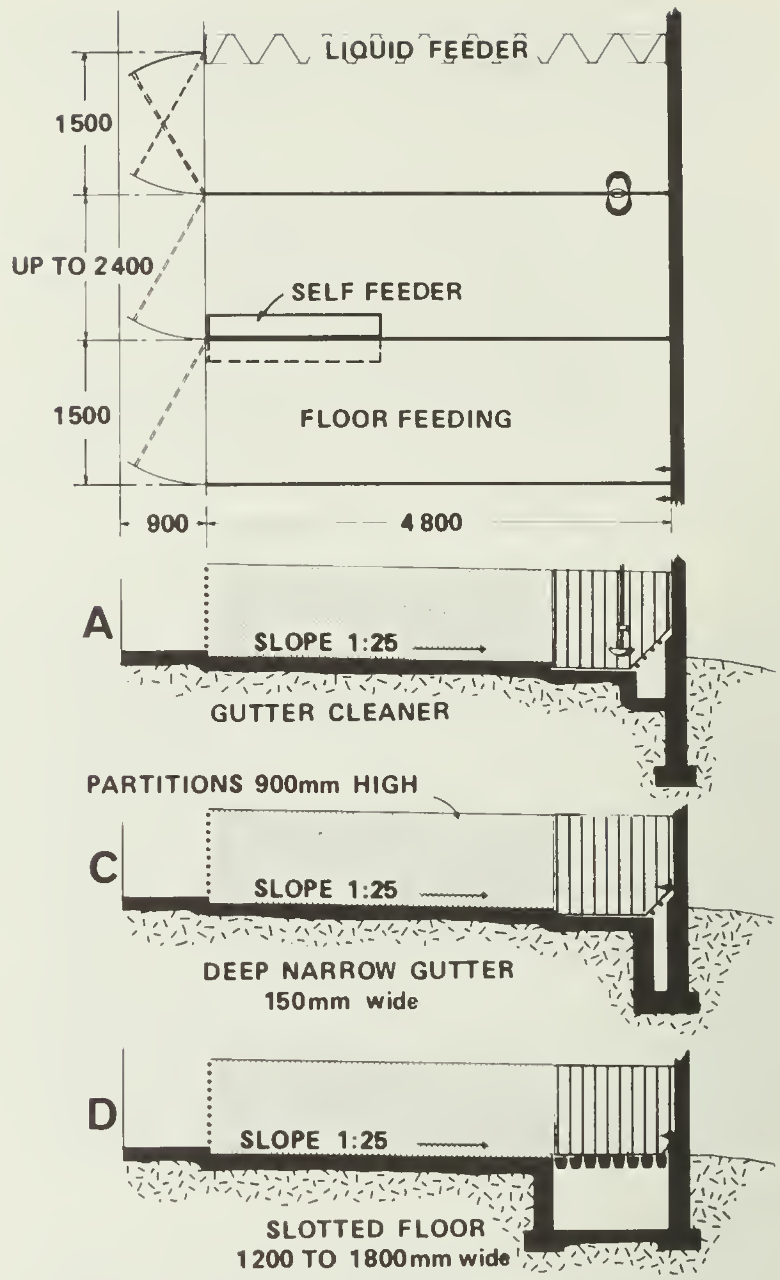


Figure 15. Growing-finishing pens with three feed systems and three manure systems.

quirement. The usual arrangement is to replace the front part of every second pen partition with a double-sided self-feeder. Choose the narrowest feeder available to save valuable pen-space, and locate it adjacent to the front corner of each pen to encourage good housekeeping in the sleeping and feed area. An auger or chain feed conveyor suspended from the ceiling transports feed along the barn, and adjustable drop-pipes into each self-feeder regulate feed level. For high-moisture feeds use longer drop-pipes to minimize the storage time in the self-feeder, to prevent spoilage.

Water may be supplied by a pig drinker bowl or nozzle drinker. The nozzle drinkers are becoming more popular because they are self-cleaning. Nozzle drinkers are better if designed so that the pig must place his mouth over the outlet in order to operate the valve; this helps to prevent excessive spillage. Watering units may be

mounted near the outside wall (Figure 15-B), or in pairs back-to-back at the partition (Figure 15-A). To prevent freezing, mount the water pipe a little away from the outside wall or ceiling rather than tight against the surface; never locate water piping in the path of cold air from the ventilation inlets.

As in weanling pens, veterinarians prefer solid pen side partitions, but open pen partitions reduce fighting and spooky pigs. It is essential, however to use a pen front gate of steel mesh or similar open material, for good pen ventilation.

V BUILDING ARRANGEMENT FOR SWINE PRODUCTION SYSTEMS

Building arrangements must be planned and adjusted to suit the individual farm, but some basic principles are important. Swine production causes odors, therefore swine buildings should be located downwind and well away from the farm residence and neighbors. The building site must be well drained and served with good all-weather roads. The building layout should be arranged so that points of frequent access (feed, pig loading ramp, controlled visitor entrance) require minimum snow removal and road maintenance.

For disease control, it is ideal to completely exclude visitors. All outside doors should be locked, and the front entrance should be planned to give the manager complete control. Casual visitors may be satisfied to see one or two pig rooms through observation windows from the front office or vestibule. Truckers and salesmen travelling from other hog farms are the worst risks. Important visitors (to whom the manager feels obliged to show more detail) should change into coveralls and boots provided, then step through a disinfecting footbath in the vestibule to enter.

Details of manure handling and storage systems are described later in Chapter VIII, but manure handling is so basic to the arrangement of buildings that it must be considered here. Long, cold Canadian winters prevent year-round manure spreading operations, therefore manure storage is usually required for at least 6 months. Storage volume calculations based on Table II, page 63 readily show that manure tanks or storage ponds will occupy a significant area within or near the building site.

Solar energy can be utilized effectively now or in future to reduce winter heating fuel requirements. Solar collectors function best in a south-facing wall or roof surface, therefore buildings needing the most heat should have priority here, although all components of a swine complex could benefit from improved ventilation resulting from solar heating.

Canadian swine operators prefer swine barns connected together, especially in the colder regions. Connected units provide better visitor control, easier pig transfer from unit to unit and simpler installation of services (heat, electricity, water). The main disadvantage is the risk of loosing the whole operation in case of fire; it is a good idea to divide the connected barns with concrete block fire-walls extending through the attic to the roof, and to use self-closing fire doors where appropriate. Furnace rooms similarly should be surrounded by concrete block walls or equivalent fire resistant construction, and the ceiling should be fireproofed with metal lath and plaster, or a double layer of gypsum wallboard, both with non-combustible insulation above.

To illustrate these principles, seven suggested plans for farrow-to-finish swine production systems are included here. Preferred North is shown on each plan, and important inputs and outputs are indicated by arrows, for each component building. Most of these component buildings represent detailed plans by the Canada Plan Service. Operators should re-calculate all pen requirements in planning a particular production system, and adjust for their particular situation and level of production (see Chapter III),

CONTINUOUS FARROWING SYSTEMS

Figure 16 shows the five main areas of a small swine system, all combined into a simple rectangular building to minimize cost. For a 50-sow operation, some compromises were necessary such as combining farrowing and weanling areas in one room. Below 50 sows it may not be practical to provide even this much separation between the main areas, since each area requires its own ventilation and other services. The numbers of pens in each area were calculated for a 50-sow breeding herd operation on the 8-week, early-wean farrowing pen cycle (Table 6, page 10). For logical internal traffic flow and proximity of heating and electrical services, the service area is located between Farrowing and Growing/Finishing; access to this service area must be from two sides of the barn, requiring extra road maintence. Manure storage can't be easily brought to one location, another disadvantage of this straight rectangular arrangement.

Traffic flow and access to services can be considerably improved by using an L-shaped or T-shaped building

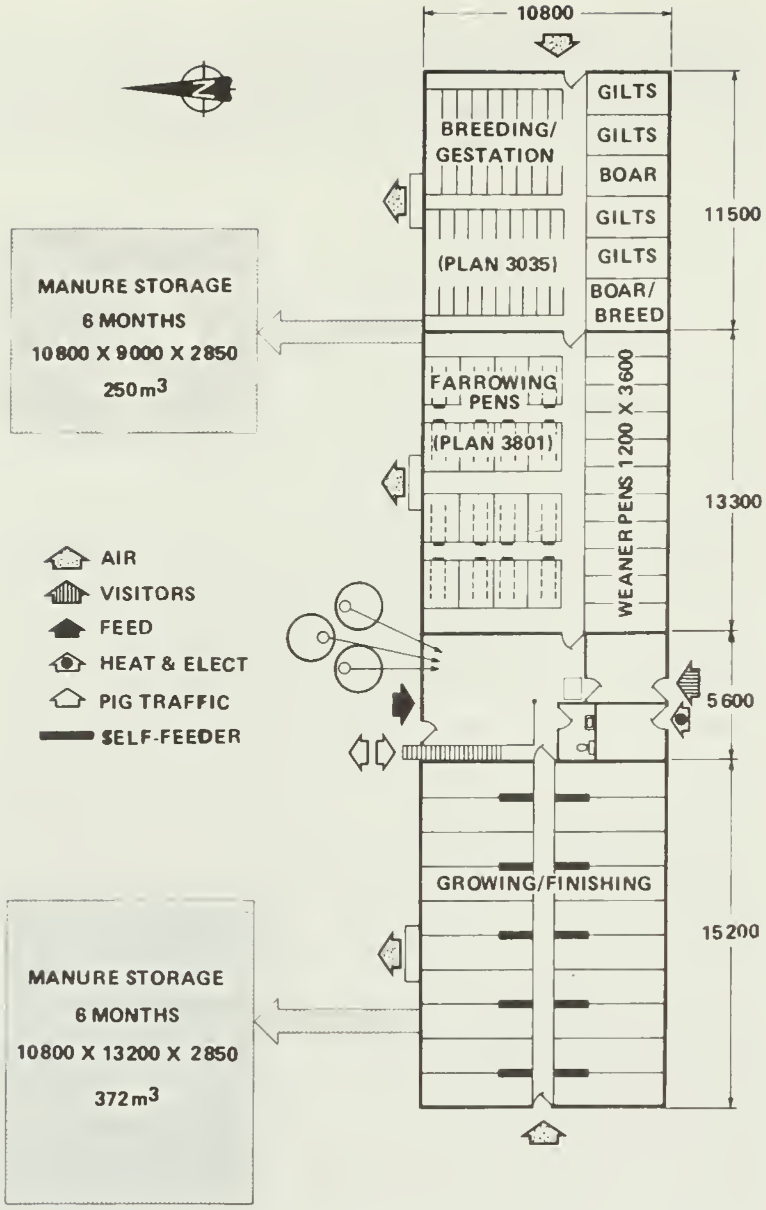


Figure 16. Rectangular plan, farrow-to-finish system, continuous farrowing, 50-sow herd.

arrangement. Figure 17 shows a T-form system for 50 sows; this puts the service core at the junction of the three main pig areas. The building itself will cost more than the 'straight' plan due to the extra walls, roof valleys and gables, but short sewer lines to a single manure storage behind the barn is an improvement. With the building span not restricted to 10.8 m, the farrowing/weaner wing can be reduced to 7.2 or 8.4 m to match two rows of farrowing stalls, and the weaner area can be more easily separated as shown.

For the 100-sow herd, the same T-form arrangement can be doubled in size (Figure 18), with corresponding doubling of the required manure storage. Note that this farrowing/weaner area is laid out as in Figure 16 except that for more flexible planning the farrowing stall rows run the length of the room instead of across the room. Where manure from the farrowing stalls will be hand-scraped to a collector, short rows of stalls are preferred.

The L-shaped arrangement (Figure 19) makes excellent use of space for the larger herds. Locating the service area at the outside corner gives more exterior wall space for access to external services (feed, electric power, ventilation air, visitors' entrance), thus overcoming some problems found with the rectangular plan (Figure 16). The only disadvantage is the construction of roof valleys where the two wings connect. A long, rectangular manure storage as shown is best here since it allows short, direct manure pipes. If possible, choose a site with enough natural slope from barn to storage for a simple gravity-flow manure system.

MULTIPLE-ROOM GROUP FARROWING SYSTEMS

For herds over 100 sows, the advantages of group farrowing were discussed in Chapter III. Figure 20 shows one possible 100-sow arrangement with a farrowing wing cross-divided into four rooms for group farrowing. This is a simple and popular arrangement, and the long hallway, though it seems to waste space, does provide a suitable plenum for preheating the winter ventilation air. This arrangement is easily altered to 3-room group farrowing, with rooms cycling each 9 weeks. The T-shaped arrangement of the weaner area helps keep the plan more compact.

Space for manure storage may be restricted, or a high groundwater table may dictate manure storage mostly above grade; here concrete silos up to 2.7 m high can provide the most appropriate long-term storage. In Figure 20, manure flows by gravity from nearby farrowing, weanling and growing/finishing barns into a short-term holding tank; from this an electric or tractor-powered manure pump transfers manure to either of two manure silos. Manure from the more-remote breeding/gestation area is pumped underground or through the barns to the holding tank.

For a more space-saving arrangement of the four-room farrowing barn, see Figure 21. Here the major building components are separated for fire protection. Optional 'solid' manure-handling can be provided for the breeding/gestation and farrowing barns where pens may be bedded with straw, etc. A gutter cleaner for the farrowing unit would have to be four separate units (one for each room), or to be more practical, a short loop under the hallway between the four rooms. A longer gutter cleaner loop connecting through four rooms would eliminate any disease-control advantages of the four-room management system.

For larger units (200 sows), Figure 22 shows an expansion of the basic farrowing/weanling arrangement shown in Figure 21. To keep short rows of farrowing stalls, the barn span is increased for two rows of farrowing stalls per room. Breeding/gestation and

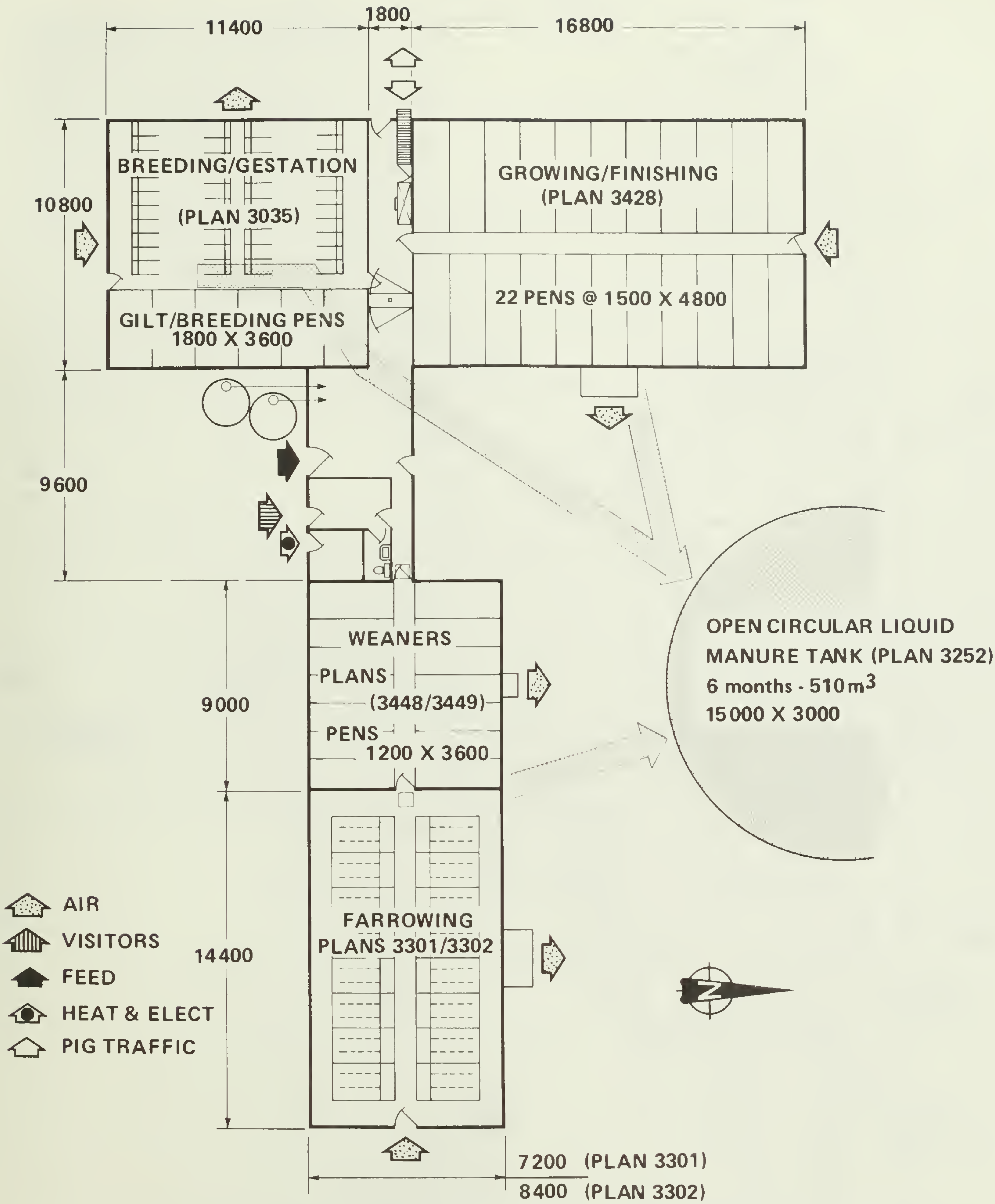


Figure 17. T-shaped farrow-to-finish system, continuous one-room farrowing, 50-sow herd.

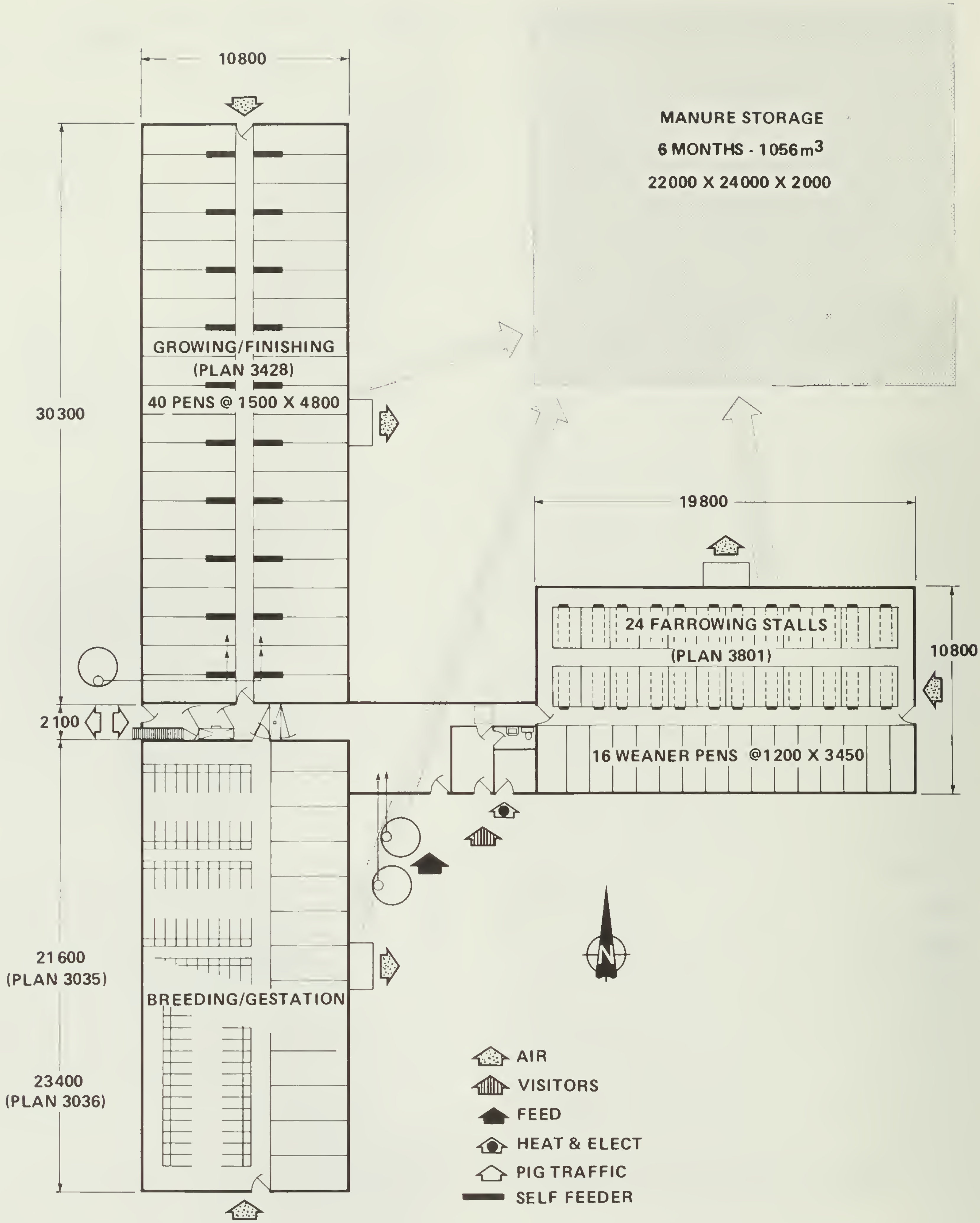


Figure 18. T-shaped farrow-to-finish system, continuous one-room farrowing, 100-sow herd.

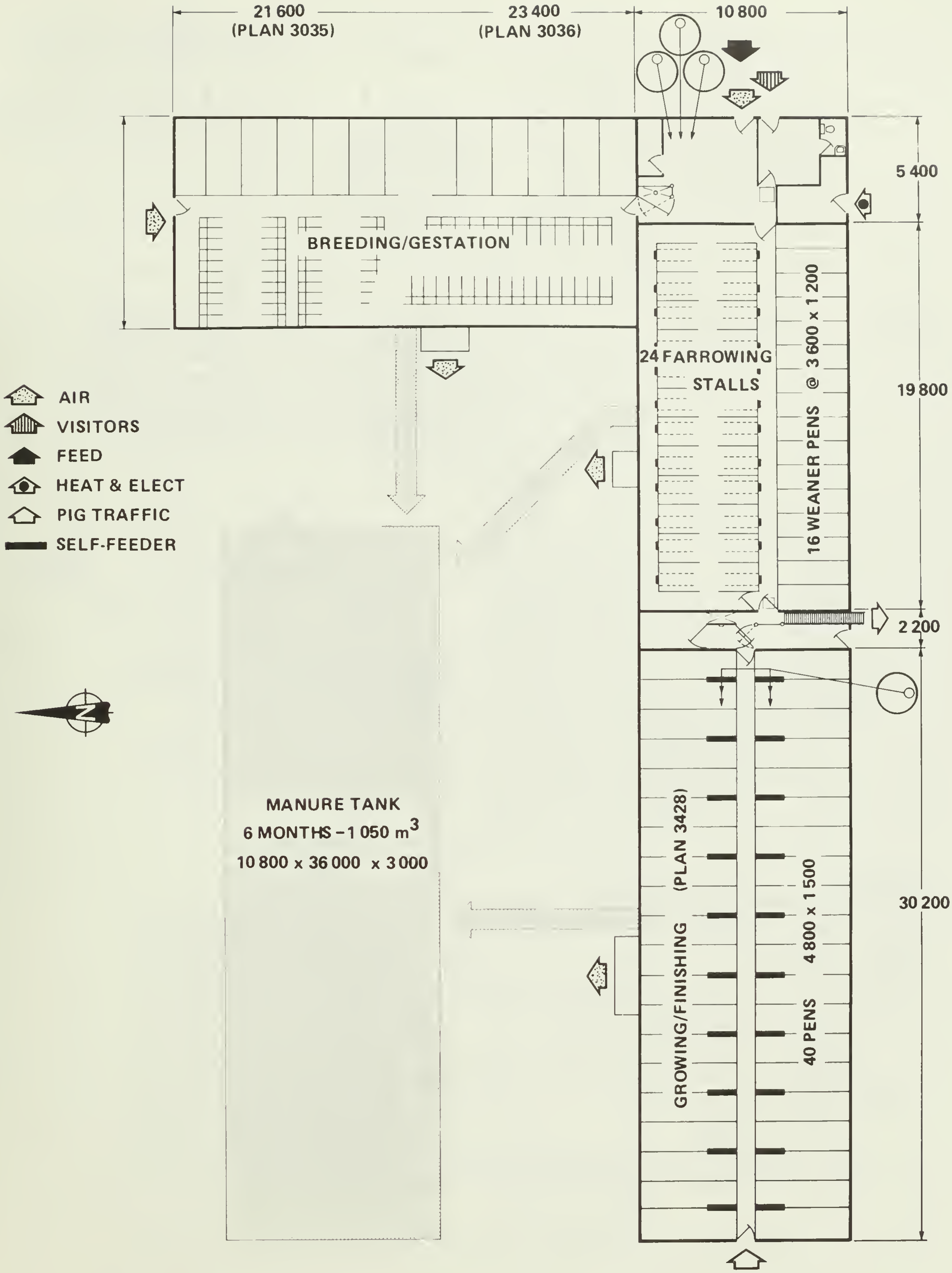


Figure 19. L-shaped farrow-to-finish system, continuous one-room farrowing, 100-sow herd.

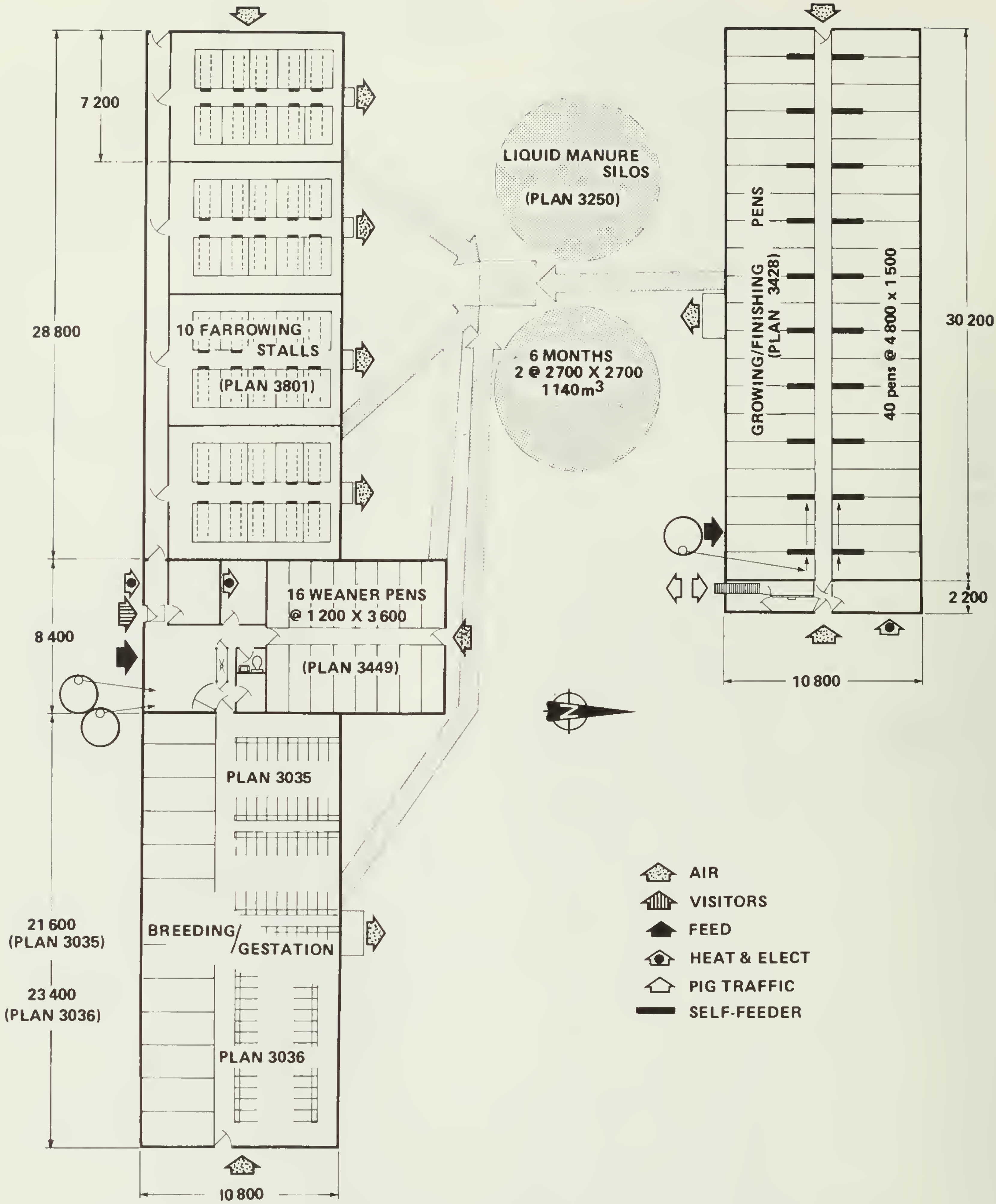


Figure 20. T-shaped farrow-to-finish system, four-room group farrowing, 100-sow herd.

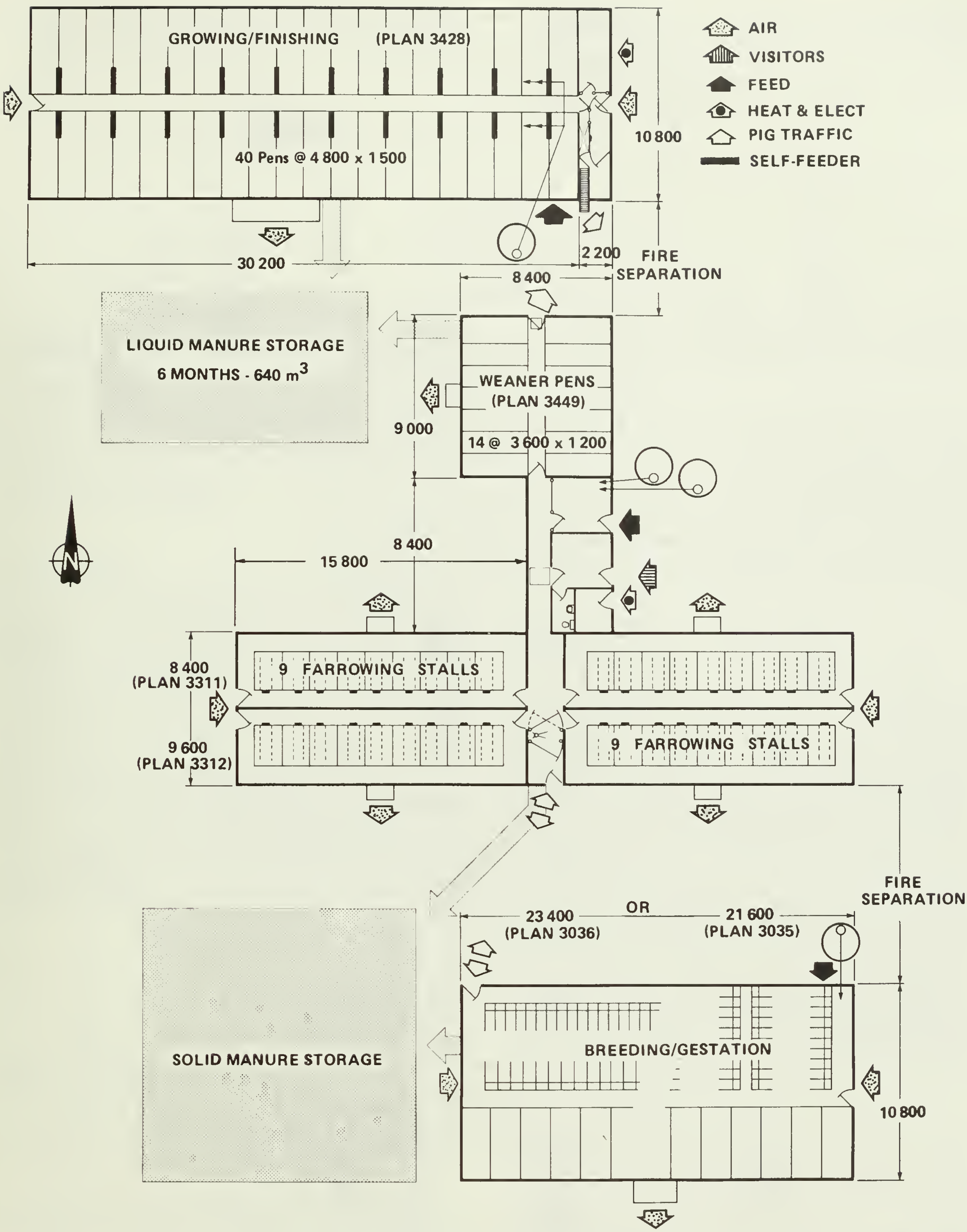


Figure 21. Farrow-to-finish system, four-room group farrowing, 100-sow herd.

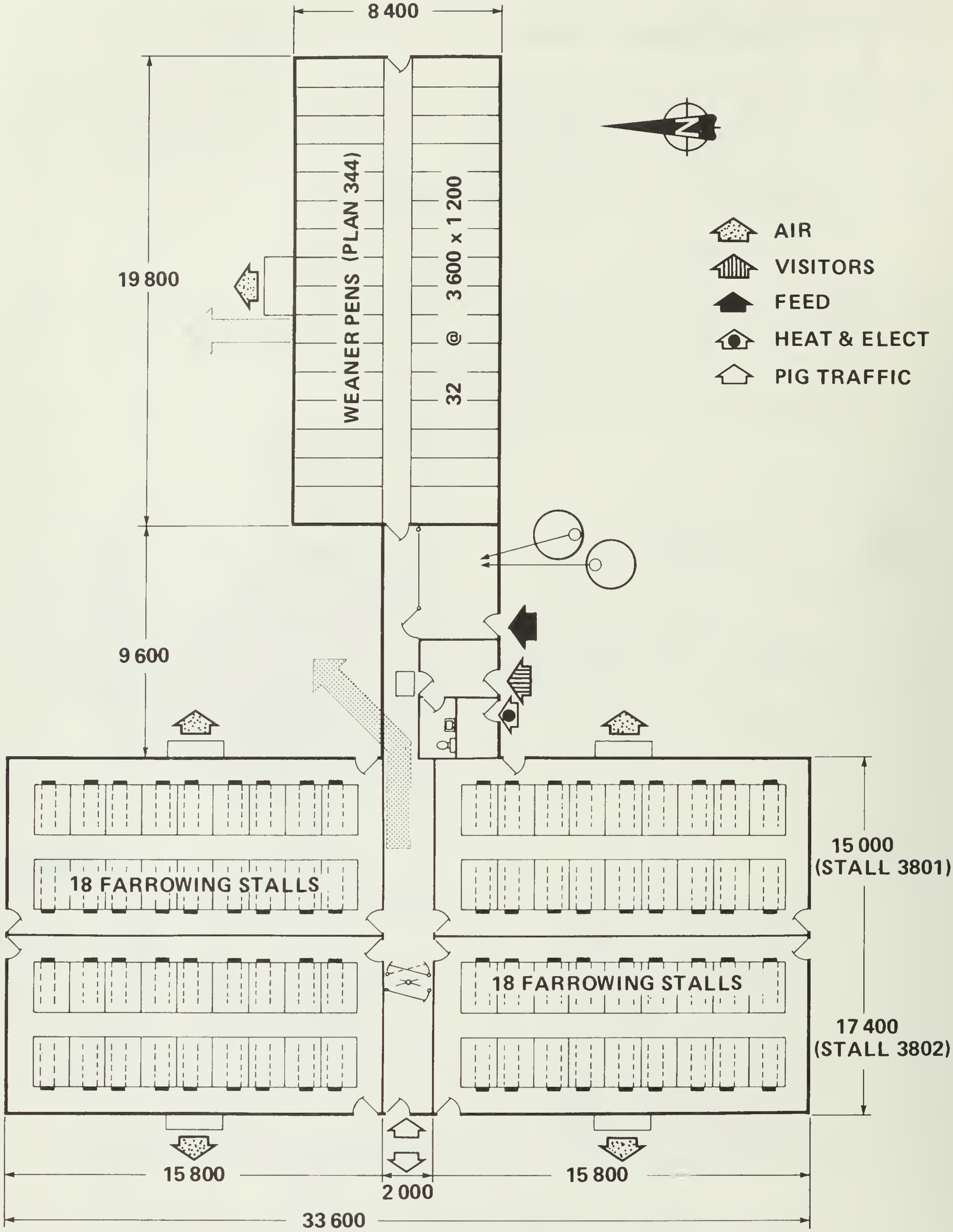


Figure 22. Farrowing-to-weanling system, four-room group farrowing, 200-sow herd.

growing/finishing units are not shown in this plan; if located at the same site as farrowing/weanling, they could be arranged such as in Figure 21 but doubled in length.

Ventilation is discussed later, in Chapter VII. It is important to note here, however, that ventilation fans should exhaust as far away as possible from the fresh air inlets. Note in Figure 19, for example, that exhaust fans from the breeding and finishing units discharge away from the farrowing and weanling units where younger pigs are housed.

VI. CONSTRUCTION

The requirements of a confinement-housed swine herd, and the type, size and arrangement of components to serve these requirements have been outlined in the previous chapters. The best types of pens and the arrangement of the housing areas are based on sound management systems with both the animals and the operator in mind. We must now construct the buildings for the job to be done.

THE BUILDING

New swine buildings are most logically of single-storey, insulated frame construction. This is the lowest-cost method of providing the well insulated structure that is necessary for any part of the production system. For ease of construction and possible future modifications, trussed rafter systems are almost always used. Figure 23 shows a cross section of a single-storey insulated farm building with trussed roof. All building widths suitable for swine housing can be constructed with this system. The post-free interior makes pen layout and pen construction easy. Difficulties in fitting commercial equipment are avoided now and in the future. A flat ceiling is better for most ventilation systems. Roof trusses can be built on site by the farmer or contractor, or they may be purchased ready-made from prefabricators.

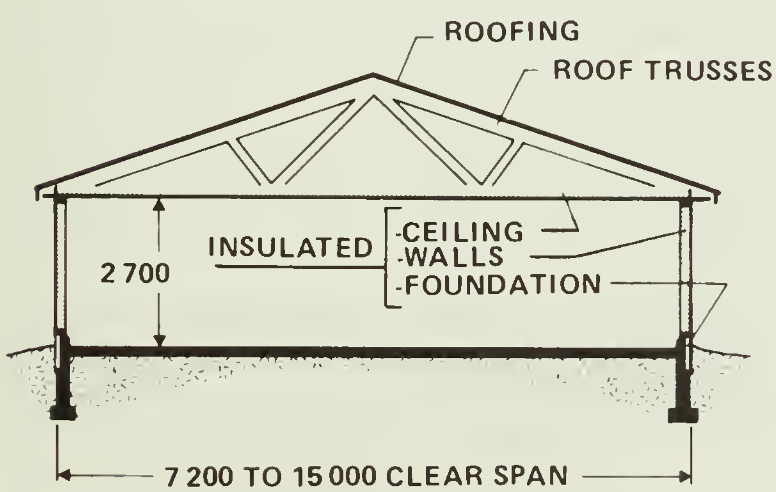


Figure 23. Single-storey insulated construction with clearspan trussed roof.

Windows are normally omitted in animal rooms. They do not make the best ventilation air inlets, they do not replace artifical light, they add unnecessary building cost and they increase winter heat loss. Air inlets can be constructed along the sidewalls or on the center line at ceiling level. It is essential to choose a ventilation inlet system that will work with the type of building and room arrangement chosen (see Chapter VII).

SINGLE-STOREY OR TWO-STOREY CONSTRUCTION

There is little to justify construction of a two-storey barn for swine. The second floor requires posts in the first floor area which almost invariably restrict the layout and construction of pens. Air inlet ducts are restricted in location and more difficult to construct. If the second floor area is used to store bedding, it is expensive storage space for the quantities of bedding required, if in fact bedding is to be used at all. If the second floor area is being planned as a second level of swine housing, it should be noted that this saves very little in building costs per animal. Constructing a second floor with the correct slopes, curbs and gutters may be difficult, if not impossible. Even with a mechanical lift or elevator installed, choring will be less convenient for the operator. It is not likely that a two-storey arrangement can be laid out without compromise in pen arrangement or space utilization.

OTHER BUILDING CHOICES

The discussion on buildings and construction to this point has considered only new buildings of a specific type. No one expects that all swine herds will one day be housed in single-storey, wood-frame, trussed-rafter buildings. Since you may be facing other choices such as remodelling, expanding or selecting one of the many other types of new buildings, the following series of questions can be used as a check list to evaluate the choices available to you.

CHECK LIST FOR ASSESSING A PROPOSED BUILDING SITE AND BUILDING FOR A NEW OR REMODELLED SWINE FACILITY

1. Is the site and plan approved by local authorities?
2. Is the location far enough from houses, roads and lot lines?
3. Is the location close enough to farm lanes, power, water?
4. Is the location well drained?
5. Is the proposed arrangement expandable?
6. Is there adequate fire separation from highly combustible buildings?
7. Will exhaust air from one building or area enter the inlets of another?
8. Is there a good location for a manure storage convenient to the points where manure comes out of the buildings?
9. Will the layout provide a smooth movement of feed, animals and manure without spreading disease from one area to another?
10. Is the building to be remodelled the right size or capacity?
11. Is it the right width for suitable pen arrangement?
12. Can it be insulated economically?
13. Can it be ventilated?
14. Can separate areas be ventilated and heated separately?
15. Can the floor slopes, curbs and manure gutters required for the pen system be constructed?
16. Can pens and alleys be arranged without restrictions now and for future remodelling?
17. Is the cost commensurate with facilities obtained?

CONSTRUCTION DETAILS FOR INSULATED WOOD-FRAME WALLS

Figure 24 shows a cross section of an insulated stud-frame wall on an insulated concrete foundation. Wider 38 × 140 mm studs spaced out at 600 mm centers provide for a better-insulated wall; stud spaces are filled with friction-fit glass fiber insulation, RSI-3.5.

Ceilings similarly can be insulated most economically by fitting RSI-3.5 glass fiber insulation between trusses above the ceiling and vapor barrier. It is more important to carefully fit the insulation to eliminate voids and spaces than to add more insulation depth. For the concrete foundation, attach 50 mm rigid polystyrene bead-board insulation with finishing nails to the inside face of the outer concrete form. When the concrete is placed, it bonds securely to the insulation board, and when the forms are stripped, the finishing nails pull out through the insulation leaving it firmly bonded into the foundation. Perimeter insulation at the outside as shown keeps the entire foundation warmer and is much superior to using it inside the foundation. Finish the exterior neatly with asbestos cement board at the base, and with horizontal metal or other siding above.

Select sheathing exterior grade plywood is a good interior sheathing material. It adds structural rigidity to endwalls and ceilings, and can be cleaned repeatedly with high pressure washing equipment. In pig pens, however, it must be protected from chewing, by covering with a hard-finished durable material such as asbestos cement board. For sheathing on ceilings, and for walls out of reach of the pigs, some operators prefer prepainted galvanized steel roofing with joints caulked watertight and panels fastened with screws.

If the foundation wall is not required to form one wall of the manure pit or gutter, then an insulated post-frame wall is equally satisfactory. For this, construction is shown in Figure 25. Pressure-treated sawn wood poles and tongue-and-groove planking replace the concrete foundation used in conventional stud-frame walls. As a precaution, treated wood should not be used where pigs could chew it. Add a rodent guard to prevent rats from tunneling under the building. This can be a band of hardware cloth attached to the wall and extending horizontally under the surface of the ground to about 450 mm from the building. Regardless of the type of construction used, it is important to keep the area next to the building free from tall weeds, board piles and debris that could shelter rats and mice. Exterior cladding should be neatly fitted, and wall spaces between nailing girts or studs should be blocked at intervals to prevent rodents from tunneling the wall insulation.

Buildings should have good cladding and enough structural strength to stand up to wind, snow and driving rain. Figures 24 and 25 include important details taken from more complete building plans by the Canada Plan Service. Before starting a new building, obtain the complete plans which can be adjusted for climatic conditions in your area.

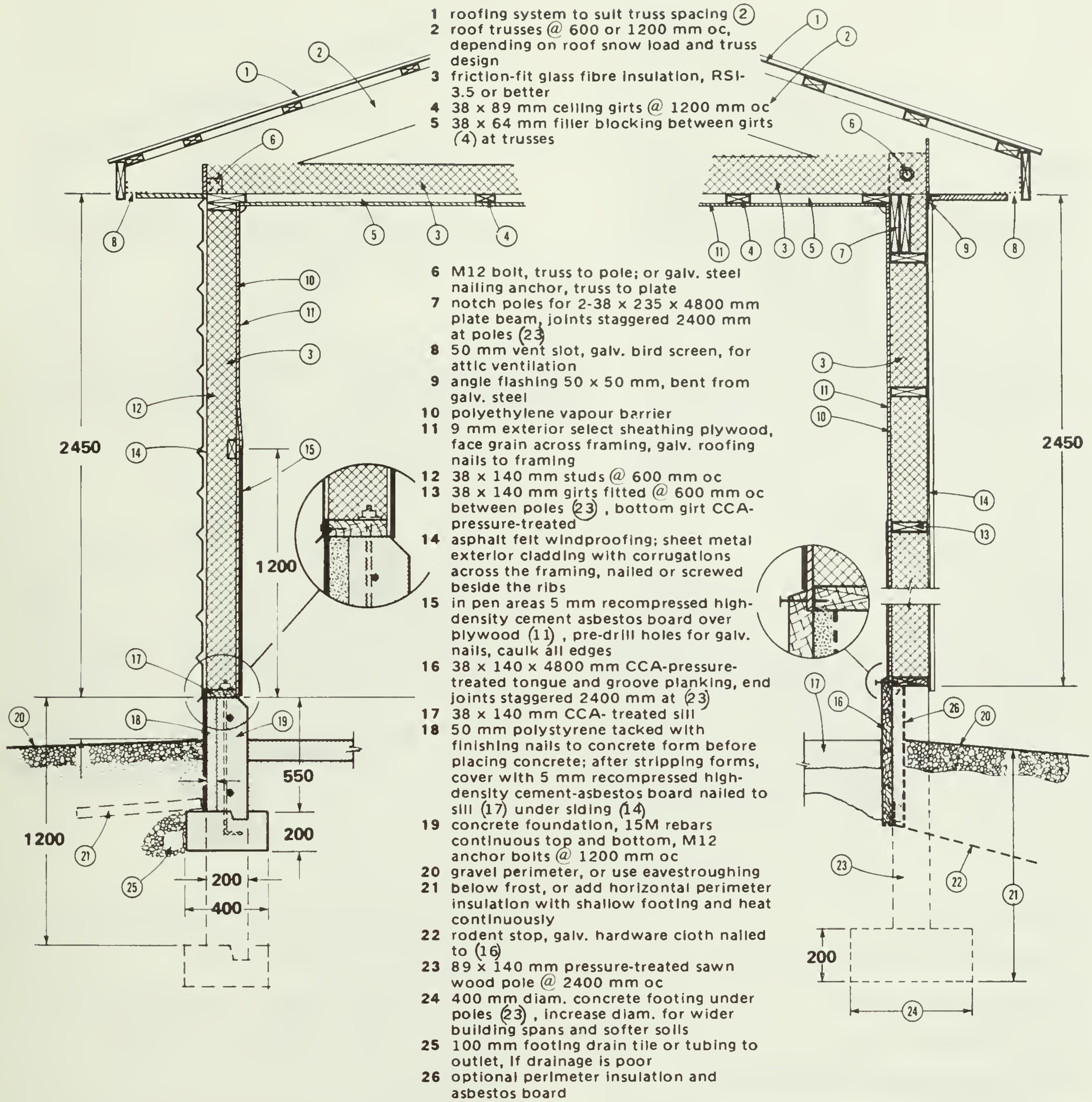


Figure 24. Insulated stud-frame wall construction.

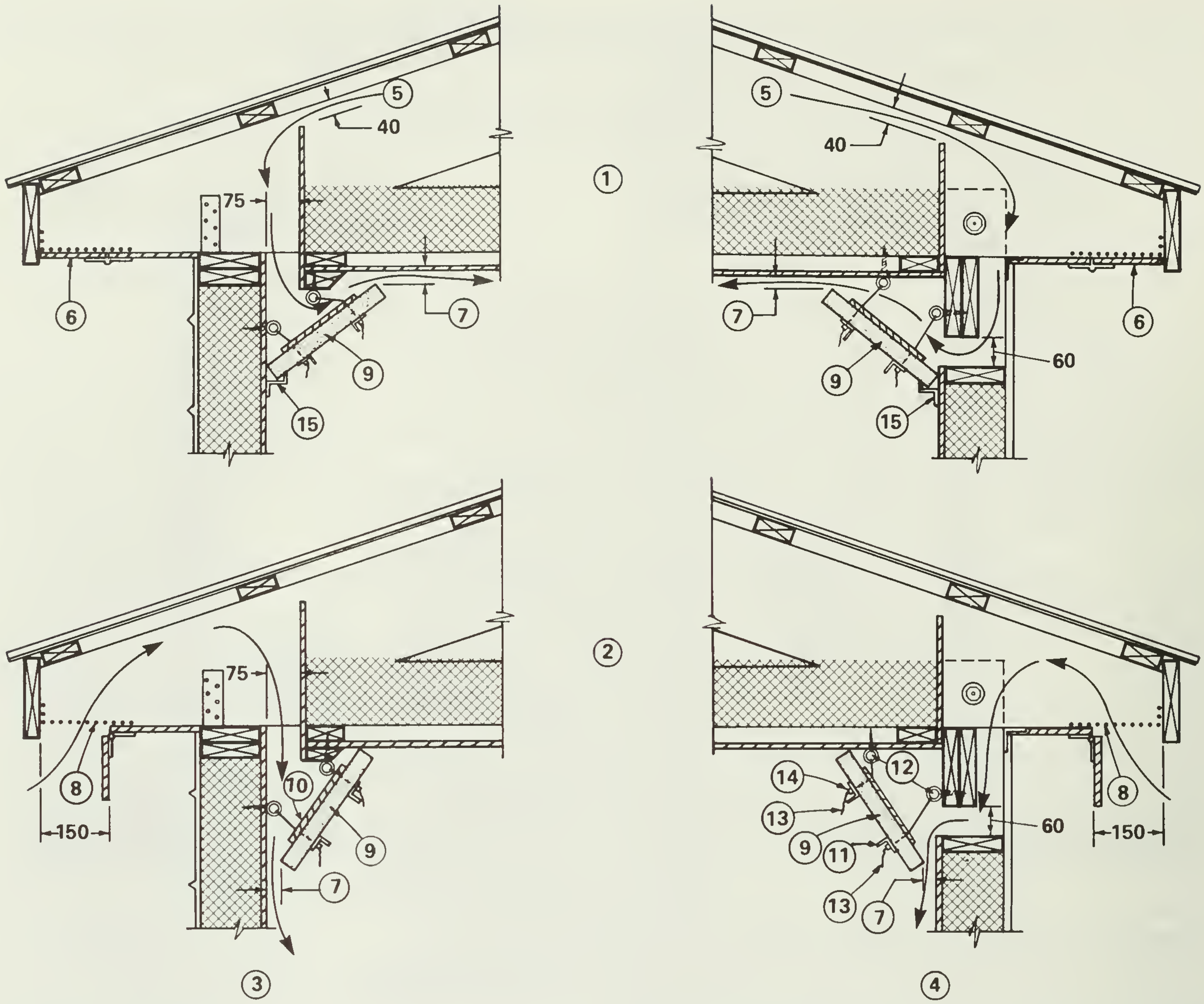
Figure 25. Insulated post-frame wall construction.

CONSTRUCTION DETAILS FOR BUILT-IN AIR INLETS

Principles of swine barn ventilation are described in Chapter VII, but some types of air inlets are easier to build into the structure of the barn at the time of construction. Details of these inlets are therefore included here.

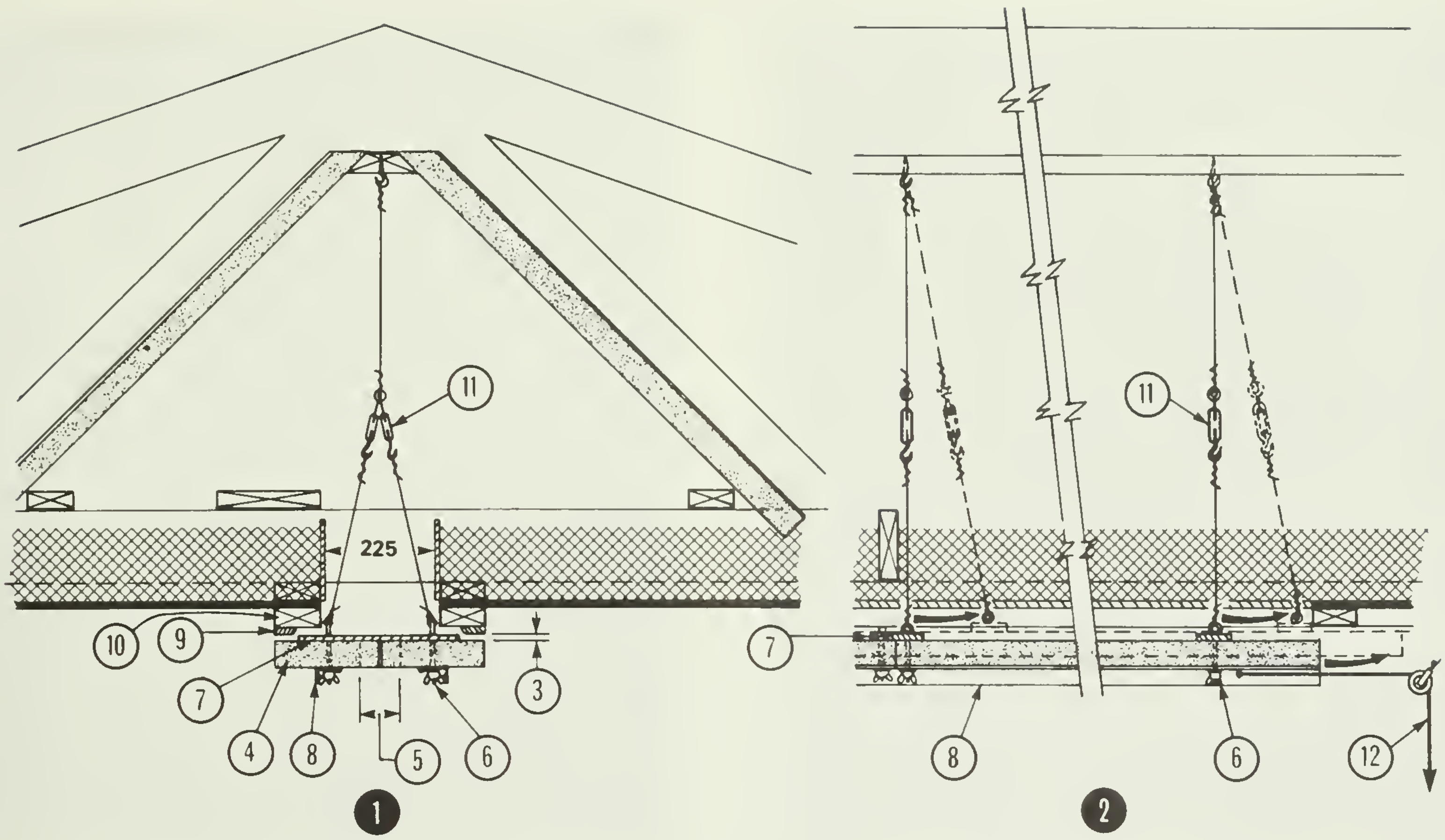
Figure 26 shows how to build an adjustable wall inlet. Rigid polystyrene foam insulation board is inexpensive and ideal for inlet flaps, as it does not warp or sweat with moisture. Be sure to use the extruded, high-density type as it is stiffer and more durable than the cheaper bead-board type.

Figure 27 shows a ceiling center inlet which receives fresh air via an insulated duct built into the attic, using the roof trusses for framework. This design has a means of precise inlet slot adjustment for the changeable spring and fall weather.



1. NORMAL SETTING
2. EMERGENCY HOT WEATHER SETTING
3. STUD FRAME WALL INLET
4. POLE FRAME WALL INLET
5. WINTER VENTILATION FROM ATTIC
6. HINGED SOFFIT CLOSED FOR WINTER
7. SLOT ADJUSTABLE 0–50mm
8. SCREENED SOFFIT INLET OPEN FOR SPRING, SUMMER AND FALL
9. 38 X 300 (or 400mm) EXTRUDED HIGH-DENSITY POLYSTYRENE BOARD CONTINUOUS
10. 6 X 75mm PLYWOOD STRIPS @ ENDJOINTS OF (9), BOLT THRU (9) TO (11).
11. GALV. SHEET STEEL ANGLE STIFFENER, 0.4 X 25 X 25 X 2400mm LENGTHS, PRE-DRILL FOR BOLTS & CORD (13) AT CENTER & 25mm FROM ENDS
12. 5mm VINYL-COVERED STEEL MARINE CONTROL CABLE RUNS THRU SCREW EYES TO WINCH CONTROL AT ONE END AND RETURN SPRING AT OTHER END
13. HEAVY (2mm) NYLON CORD, CLAMPED TO CONTROL CABLE WITH ELECTRICAL MARR CONNECTOR THRU SCREW EYE AT (12), THRU HOLE IN (9), (10) AND (11), ADJUST WITH ANOTHER MARR CONNECTOR
14. MARR ELECTRICAL CONNECTOR TO ADJUST CORD (13)
15. FOR FARROWING AND WEANLING, ADD GALV. STEEL Z-STRIP TO HINGE AND SUPPORT (9), OMIT LOWER CONTROL

Figure 26. How to build adjustable air inlets at stud walls or pole-frame walls.



1. CROSS SECTION THRU INSULATED ATTIC DUCT & CEILING
2. LONGITUDINAL SECTION AT CONTROL END OF INLET
3. CEILING SLOT, ADJUSTABLE 0 - 50 mm
4. 38 x 200 x 2 400 mm SLABS OF HIGH-DENSITY EXTRUDED POLYSTYRENE BOARD
5. OPTIONAL SLOT 0 - 50 mm WIDE FOR VENTILATION TO FLOOR DURING HOT DAYS;
6. PLATED EYEBOLTS 1 200 mm oc, WASHERS, WING NUTS, GALV. SUSPENSION WIRE
7. PLYWOOD STRIPS 9 x 75 x 267 mm @ 1 200 mm oc, PRE-DRILLED FOR 6
8. 0.4 x 25 x 25 mm GALV. STEEL ANGLES 1 200 mm LONG FOR STIFFENING, PRE-DRILLED FOR 6 AND 7 AT CENTER AND 25 mm FROM ENDS
9. SHOE MOULD, ALL AROUND
10. DOUBLE 38 x 89 x 4 800 mm JOINS STAGGERED 2 400 mm oc
11. FURNACE CHAIN OR 2 mm WIRE, ADJUST TURNBUCKLES FOR EQUAL SLOTS 3 ALL AROUND
12. PULLEY AND CONTROL ROPE TO BOAT WINCH CONTROL

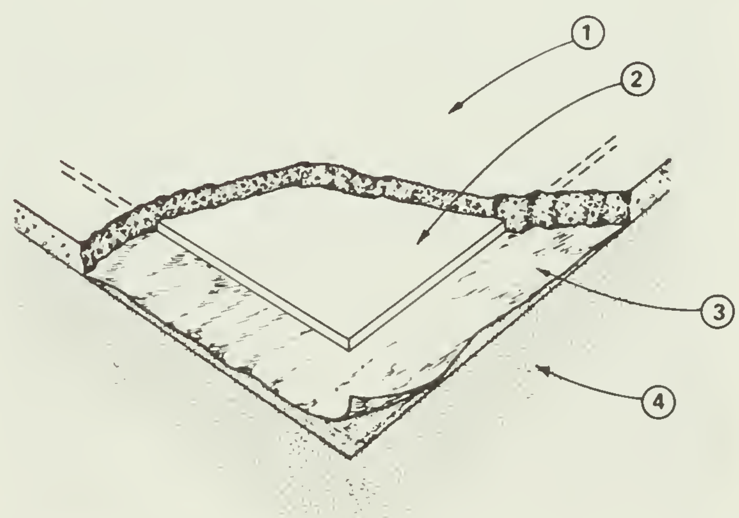
Figure 27. Adjustable center ceiling air inlet.

FLOORS

All concrete floors must be constructed on a firm base that will not settle. If fill is added, it should be sand or gravel so that it can be compacted easily. Since fill is cheaper than concrete, it is advisable to add and compact the necessary material and reduce the concrete thickness to 100 mm. Concrete floors must withstand manure and washing chemicals as well as continuous traffic. When ordering ready-mix concrete, specify at least 25 MPa strength, and do not add more water to the mix.

Floors should be given a wood float finish to provide a good footing for the pigs, especially on sloping surfaces. The small, sharp points on this roughened surface may cause irritation to the pigs for a short while until worn smooth.

The floors in weanling pens and farrowing creep areas should be insulated with rigid insulation under the concrete (see Figure 28).



1. 38 mm OF 35 MPa CONCRETE; USE 1:2:2 MIX OF CEMENT : FINE AGGREGATE: COARSE AGGREGATE (MAX. 12 mm), USE MINIMUM WATER
2. 38 mm EXTRUDED HIGH-DENSITY POLYSTYRENE INSULATION BOARD
3. 100µm POLYETHYLENE MOISTURE BARRIER
4. SAND FILL, LEVELLED, DAMPENED AND COMPACTED SMOOTH AND FLAT

Figure 28. Insulated concrete floors.

Good sanitation calls for disinfecting footbaths at strategic locations such as the front entrance and the doorways between adjacent animal areas. For foot traffic only, use an easily cleaned plastic footbath pan. Where feed carts must pass through, construct a 50 mm recess in the concrete floor. This must be wide enough for the feed cart wheels and at least as long as the circumference of the largest wheels.

To keep footbaths effective, keep a supply of disinfectant nearby and provide a handy tap or hose. For cleaning, recessed footbaths should have a stopper and a drain pipe leading to the nearest gutter.

PARTITIONS AND GATES

The first step in selecting suitable partitions is to consider what is required in each situation. Veterinarians recommend that partitions between adjacent pens be solid, but a good compromise is 450 mm of solid curb with open fencing above. This prevents the transfer of manure from pen to pen. Solid partitions are more easily cleaned as the spray from a high-pressure washer is fully captured on solid surface. One pen can be washed without flushing the manure into the adjacent pen. Solid partitions are most commonly constructed of concrete or hardwood planking. Concrete partitions can be cast in place or cast on the floor and tilted into place. Hardwood partitions are best constructed with planking that has been dressed to 32 mm to fit into 38 mm steel channel. Steel channel posts can then be used to hold the planks firmly and with flush edges. Baby pigs should have solid partitions. In this case the choices are 5-ply plywood, cast-in-place concrete or galvanized steel.

Open partitions should be used between pens and passages so that there is a minimum of interference with the air movement. A wide variety of commercially made partitions are available, or open partitioning can be made on the farm. Some common materials used are 6 mm rod mesh with 50 × 150 mm spacing, black pipe and reinforcing bars. One panel usually consists of a pipe frame to which the rod mesh is welded. Or you can complete the panel using 9 mm steel spindles spaced 125 mm on center. The size of the pipe frame will vary from 1 to 1 1/2 inch depending on the length of the panel.

For partitions between pens it is common to use a concrete curb rather than a bottom pipe. This adds strength and lessens the contact of steel with manure. In some cases, the 6 mm rod mesh has been used without a top pipe frame, but if it is not crimped, more posts will be required to support it adequately. No special coating is required to insure a long life, provided the steel does not have continuous contact with manure. It has been found that oils from pigs' skin help to resist rusting. The mesh, however, is more easily cleaned if it has a surface coating that fills and smooths the corners of the crossed rods. Hot-dip galvanizing, or structural steel paint that produces a plastic surface, have been used successfully. Figure 29 illustrates a variety of farm-made partitions.

Steel posts are best for partition corners and gates. Posts can be 1 1/2 or 2-inch black pipe, double or triple 38 mm channel, or size 30 M reinforcing rod. Make simple gate hinges by welding interlocking sections of 3/4-inch pipe to post and gate and by inserting a 9 mm rod for the hinge pin (see Figure 30).

Although it is quite logical to anchor posts by setting them in concrete during the construction of the floor, it can facilitate construction to anchor the posts after the floor has been constructed by drilling the floor and installing expanding anchor bolts. Some contractors prefer to weld the partition frames to the posts, forming rigid frames that require less anchor strength than unsupported posts. It is preferable to weld after the posts have been anchored.

The recommended heights for partitions are given in Table 8.

TABLE 8. REQUIRED PARTITION HEIGHTS

Application	Height, mm
Creep Partitions	
– to 4 weeks of age	400
– to 8 weeks of age	600
Weanling Pen Partitions	800
Finishing Pen Partitions	900
Sow and Boar Pen Partitions	1 100

Figure 29. Types of farm-made partitions for swine pens.

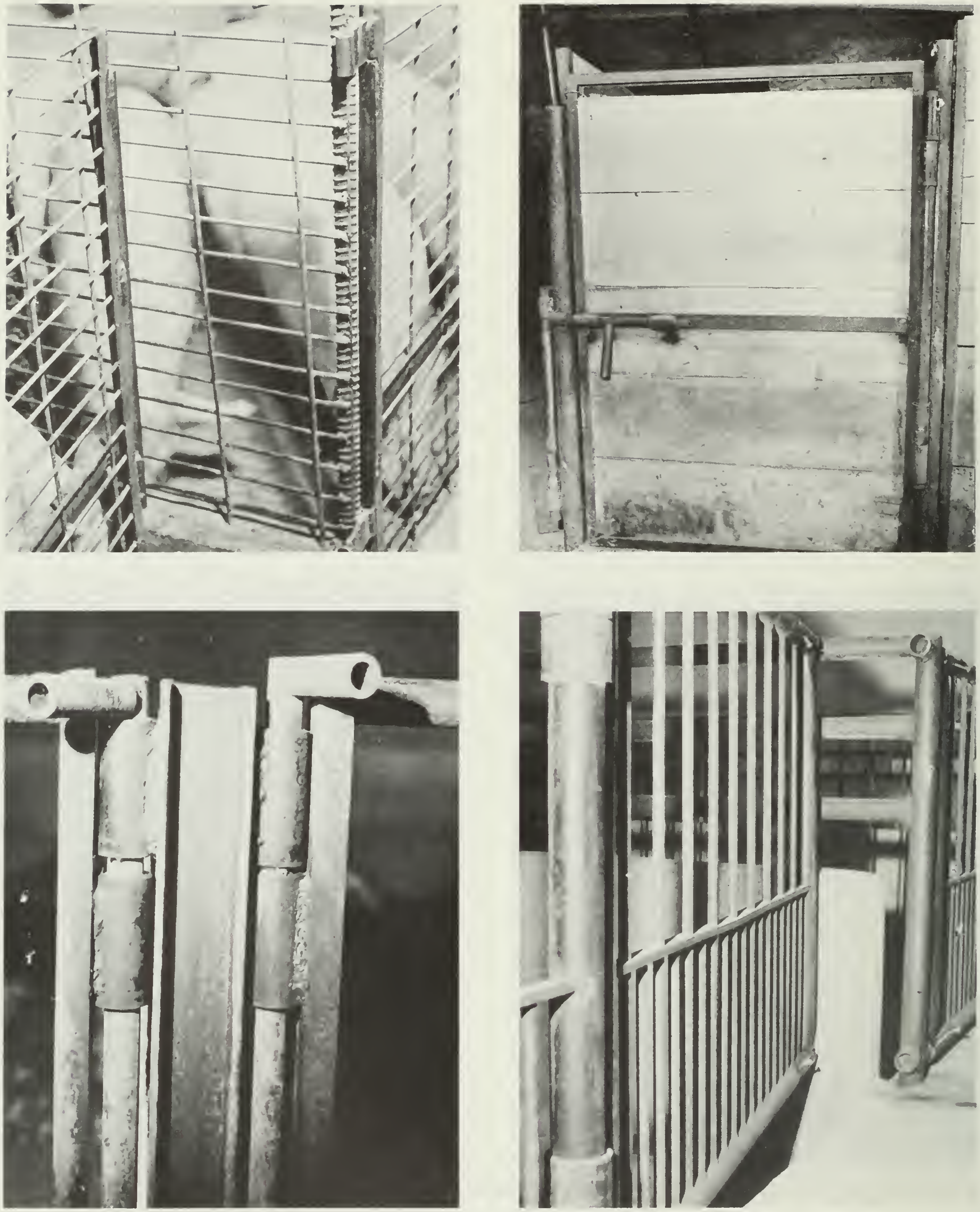


Figure 30. Typical gates for swine pens.

For profitable pig production, it is extremely important to provide adequate fresh air, and to regulate temperature, humidity and air flow according to the special needs of the pigs in each age group. Chapter I includes research results which demonstrate the spectacular way growing pigs respond to comfortable temperatures. This chapter now outlines the principles of good ventilation, and gives information on how good environments can be provided for breeding, farrowing and growing pigs.

HOW VENTILATION WORKS

Figure 31 illustrates the winter ventilation problem for the growing pig in an insulated building with exhaust ventilation. The pig produces heat which helps to maintain a comfortable room temperature. He also gives off water vapor, from his breath as well as from wet floors. carrying the 0.4 g of water vapor would be at only 3% relative humidity. If necessary (at 100% relative humidity), it could carry over 30 times as much water vapor as the cold air outside.

It is not desirable to allow the room air to go up to 100% relative humidity; 75% is a more practical maximum for a dry comfortable barn and healthy pigs. So moisture from the pigs and the pens evaporates into the room air until each kg of mixed room air is at 75% relative humidity, and holds 8 g of water. This is 20 times as much moisture as the cold incoming air could carry. Exhaust fans remove this warm moist air at a controlled rate. Each kg of air comes through the inlets carrying 0.4 g of water, and later goes through the exhaust fans carrying 8.0 g, thus removing 8.0 — 0.4 = 7.6 g water vapor.

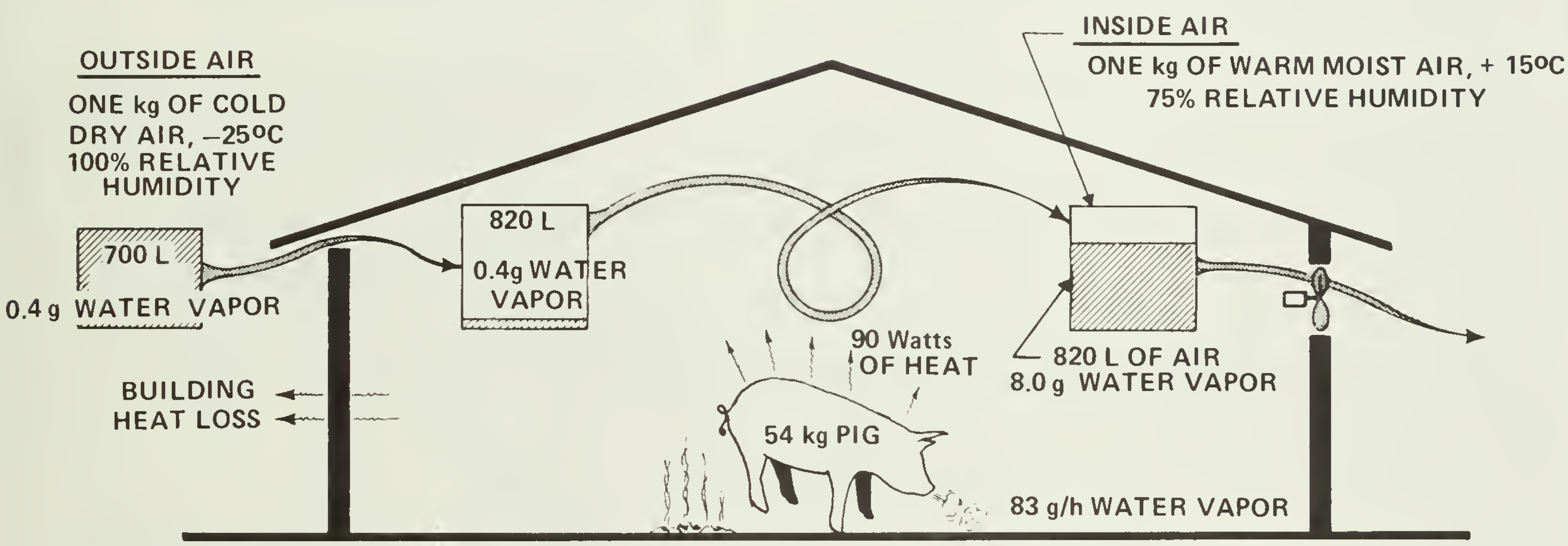


Figure 31. Winter ventilation for the growing pig in a controlled environment.

This water vapor must be drawn off by the ventilation system, otherwise it will accumulate in the building until the air becomes so damp that vapor will condense on cool surfaces such as walls and ceilings.

Good ventilation controls humidity by removing water vapor as fast as it is produced. Note in Figure 31, for example, that one kg of *cold outside* air at conditions stated occupies 700 L and holds only 0.4 g of water vapor even when 'saturated' (100% relative humidity). This cold air is drawn into the barn through the air inlets where it then mixes with warm air inside. Warming one kg of dry air up to 15°C causes it to expand (from 700 to 820 L), and in addition greatly increases its capacity to hold water vapor. This air, now warmed and dry, still

Since research has shown that the pig in this example produces about 86 g of water vapor per hour (see Table 9), we can now calculate the ventilation rate required to control humidity as follows:

$$\text{Ventilation rate} = \frac{86\text{ g/h water vapor}}{7.6\text{ g water/kg air}}$$

$$= 11.3\text{ kg air/h}$$

Since exhaust fans are rated in litres of air per second (L/s), not kg of air per hour (kg/h), this is changed as follows:

$$\frac{11.3\text{ kg/h} \times 820\text{ L/kg}}{60 \times 60\text{ s/h}} = 2.6\text{ L/s, for one pig}$$

Calculations similar to this were used to prepare the ventilation recommendations in Table 10.

THE HEAT BALANCE PROBLEM

Unfortunately, it takes a lot of heat to warm up this much incoming cold air, and some more to supply the heat that escapes out through the ceiling, walls and foundation. During cold weather, pigs (especially small ones) do not always produce enough heat to maintain good ventilation and at the same time keep the temperature up. If ventilation rate is maintained, the temperature will drop, and if the exhaust fan thermostat is set at 15°C, for example, the fan will cycle on and off automatically to balance the heat account. This cuts the ventilation rate to a fraction of that required to control moisture, and the humidity goes up. Sick pigs and a wet building are inevitable if the situation goes uncorrected.

An obvious answer is to add supplemental heat to make up the deficit, but this over-simplifies the problem. Read on.

VENTILATION RATE AND HEAT BALANCE

As outside temperature rises, the rate of ventilation must be increased as well since warmer outside air will enter the building carrying in more heat and moisture.

With a pen floor 35% slotted, no heat would be required above −15°C outside, and the required supplemental heat below this point is much less than with solid floors. Realize however that these critical temperatures are theoretical, coming from calculations based on old research (ref. 2). Heat and moisture production of growing swine can easily vary 300% depending on time of day (and the pigs' resulting physical activity), the wetness of the floors (dunging habits) and other factors. These ventilation rates and heating requirements are therefore only estimates based on 'average' conditions.

FAN CONTROLS

Figure 32 shows another important fact. In cold winter weather the ventilation requirements are almost constant. However, as outside temperatures rise above

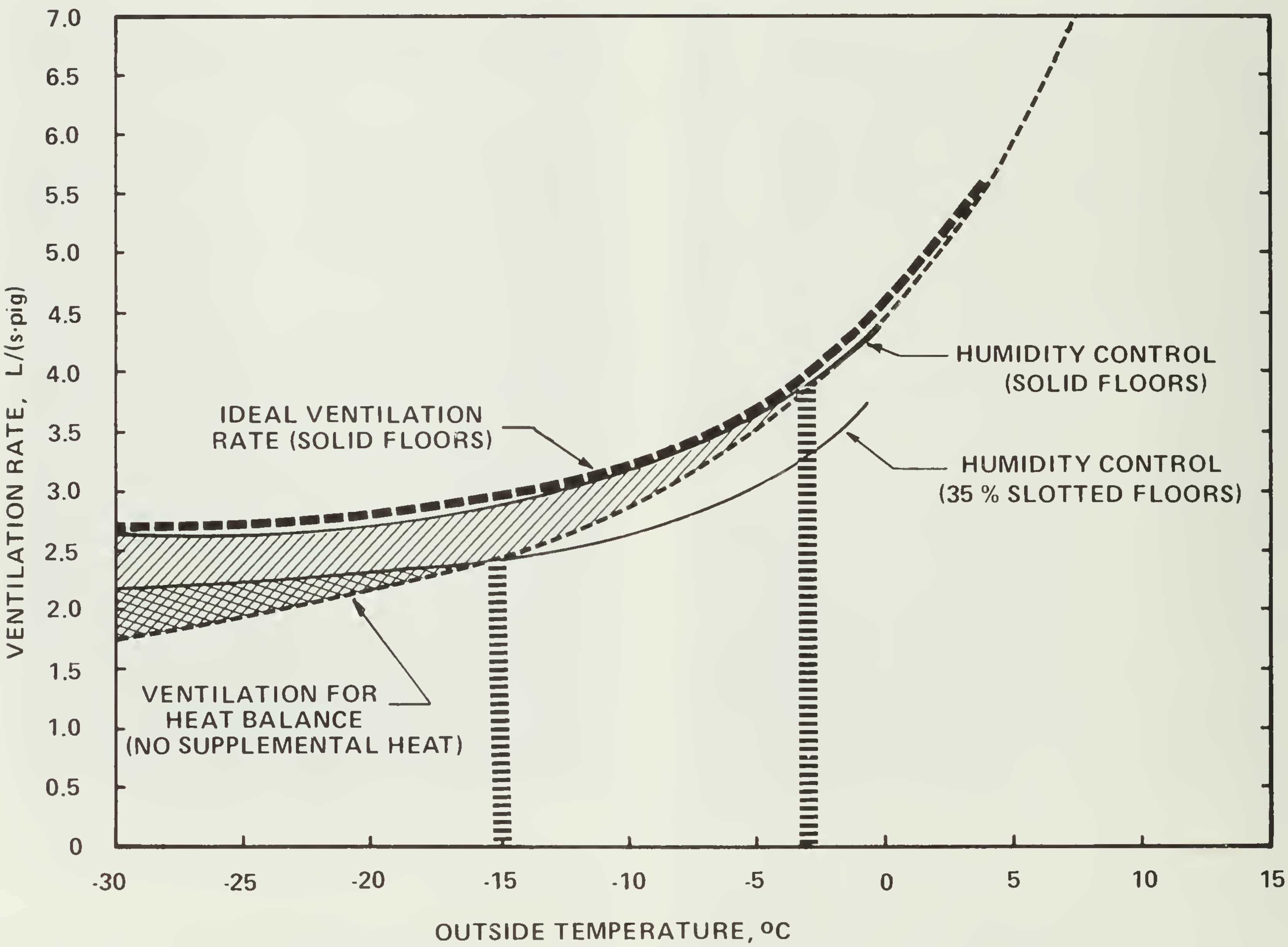


Figure 32. Ventilation rates for heat balance and humidity control in growing-finishing barns.

freezing, the ventilation rate increases rapidly. At temperatures over 20°C, the 'average' 54 kg growing-finishing pig needs about 30 L/s. This is over 10 times the average cold weather rate, and for good ventilation, fans must be chosen to give this wide range of capacities.

If a single fan is switched on and off to control ventilation rate for the whole range (for example, 2.6 L/s winter to 30 L/s summer), this fan would run less than 10% of the time in cold weather, and the barn temperatures would fluctuate badly. Figure 33 shows a better system with three fans (or sets of fans), con-

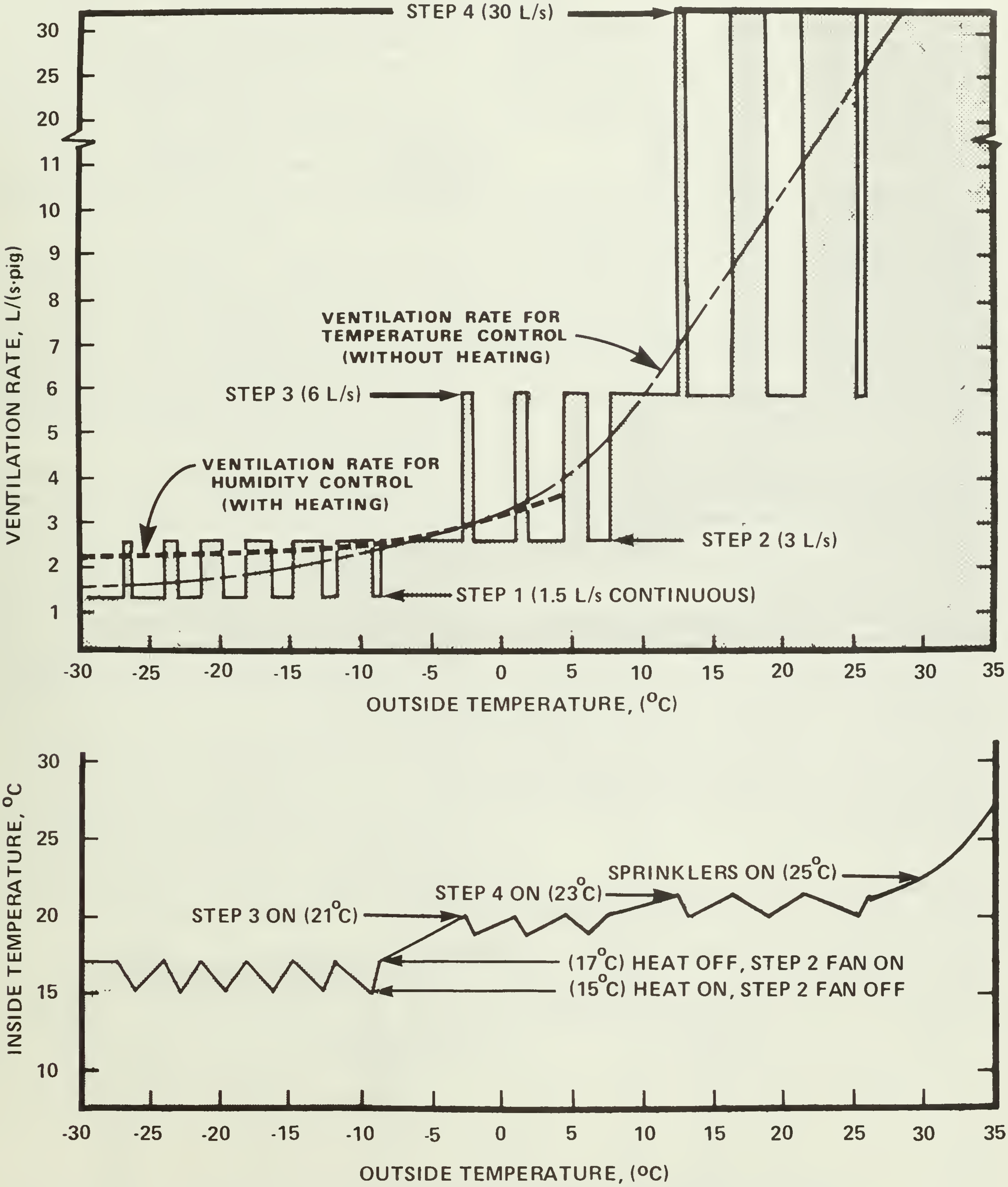


Figure 33. Stepped ventilation with interlocked heating control for a swine growing-finishing barn.

trolled with three thermostats in temperature steps to provide four rates of ventilation. The upper part of Figure 33 shows the same ventilation rate curves as Figure 32 for humidity control and heat balance. Superimposed on these curves are practical rates which can be obtained by careful selection of fan sizes and thermostat settings.

Other factors affecting ventilation include inside temperature, the size of the pigs, the type of activity (sleeping, eating or socializing), and even the type of pen floor. Table 9 shows the effects of inside temperature and floor type on heat and moisture production of growing pigs.

Notice in Table 9 that decreasing the room temperature from 15°C to 10°C would *increase* the heat production and *decrease* the water vapor production of the 54 kg pig in our example above. This indicates that if a pig barn without supplemental heat is too wet at 15°C, adjusting the thermostats down can increase the ventilation and thereby reduce the humidity problems. It is usually more profitable however to add the required supplemental heat as long as electrical or fuel energy costs less than feed energy.

Note also in Table 9 that with part of the floor slotted, the water vapor is reduced considerably. Apparently more moisture must be evaporated from a wet concrete floor than from a slotted floor area over a storage trench.

Figure 32 shows the effect of outside temperature on ventilation rates. The *heat balance* ventilation rates were based on inside air at 15°C and 75% relative humidity. These ventilation rates are the average that thermostatically controlled fans would give, without supplemental heat. If ventilation is based on removal of water vapor instead of heat, the curves are quite different. Note that below −3°C (outside) the ventilation rate for *humidity control* (solid floors) is higher than the rate for heat balance.

To put this another way, enough supplemental heat should be added to the room to bring the air represented by this 'supplemental heat zone' from outside temperature up to +15°C, to keep the barn dry and warm. This allows us to use the 'ideal ventilation rate' to maintain the best conditions for economical pork production.

It is most important that the 'Step 1' rates be *below* the minimum ventilation requirements (for humidity control), so that it can provide *continuous ventilation* even in the coldest weather. Step 1 is therefore shown at 1.5 L/s. Steps 1 and 2 can be obtained with a two-speed fan wired to run continuously at low speed until the first thermostat switches it to high speed. It is important here to select a two-speed fan that puts out about 50% of maximum air when operating on low speed; many two-speed fans run at 2/3 of full speed when switched to low, and this is not slow enough for Step 1.

To provide the type of ventilation control shown in Figure 33, thermostats must be set in temperature steps. To properly compare thermostat settings, it is important that thermostats be located all together, preferably at the center of the room to be ventilated. Mount thermostats side-by-side, at eye-level and facing a passage. Be careful not to locate the thermostats in the path of air from an inlet, doorway, or heater.

To prevent wasting heat, the heating control can be interlocked with the ventilation thermostat to be sure that heat is switched off whenever step 2 ventilation is switched on, and vice versa. This interlocking is done by using the same thermostat to control both. Many farm thermostats (Honeywell T631A, for example) have three wiring terminals leading to two-way contacts (SPDT type) so that the same thermostat can be wired for either 'heating' or 'cooling' control. Typically there is a fixed temperature differential of one or two Celsius degrees between 'start' and 'stop'. The lower part of Figure 33 shows how, in cold weather, the Step 2 thermostat keeps inside temperature cycling between 15°C and 17°C. At 17°C this thermostat starts the Step 2 fan and at the same instant stops the heating. With Step 2 ventilation ON and heat OFF, the temperature is pulled down to 15°C; the thermostat then switches the step 2 fan OFF and the heat ON, room temperature rises again to 17°C and the cycle repeats.

TABLE 9. HEAT AND MOISTURE PRODUCTION OF GROWING-FINISHING PIGS (AV WT 54 kg)

Room temp, °C	Total heat production, W/pig	Water vapor production with solid floors, g/(pig·h)	Water vapor with floors 35% slotted, g/(pig·h)
30	137	154	154
25	134	121	107
20	140	97	81
15	151	83	70
10	168	75	67

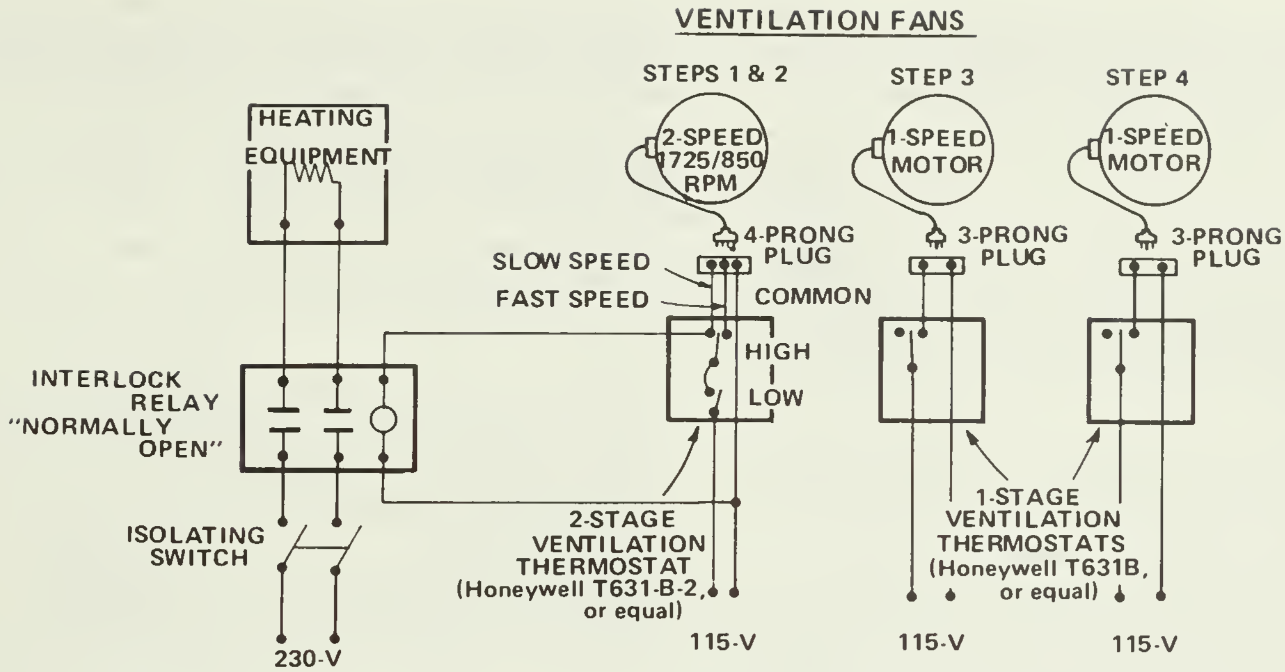


Figure 34. Interlocked heating/ventilating control with a two-speed fan for Steps 1 and 2 (four ventilation steps).

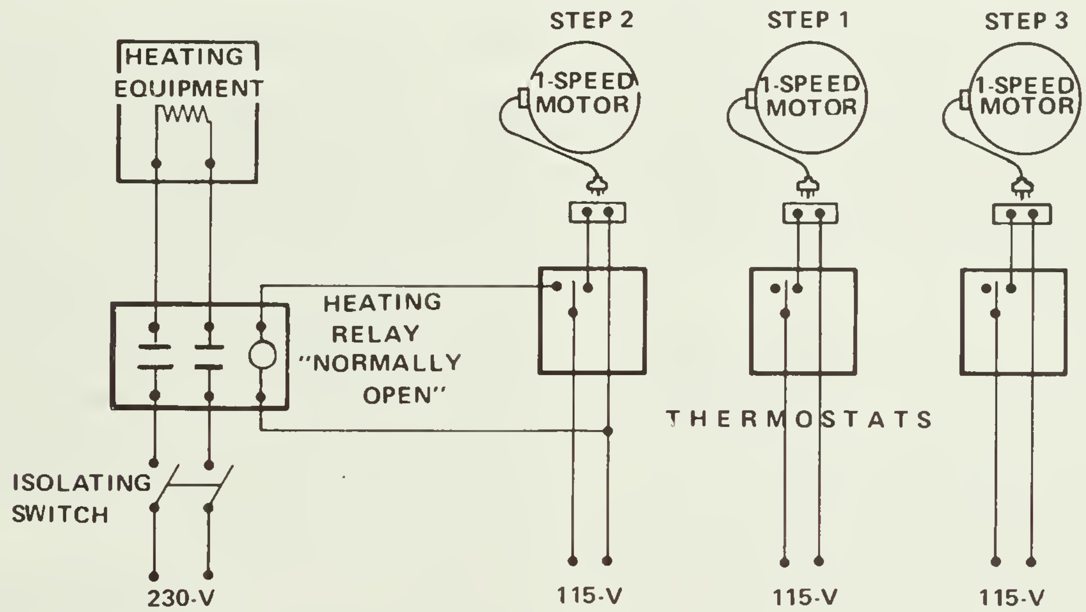
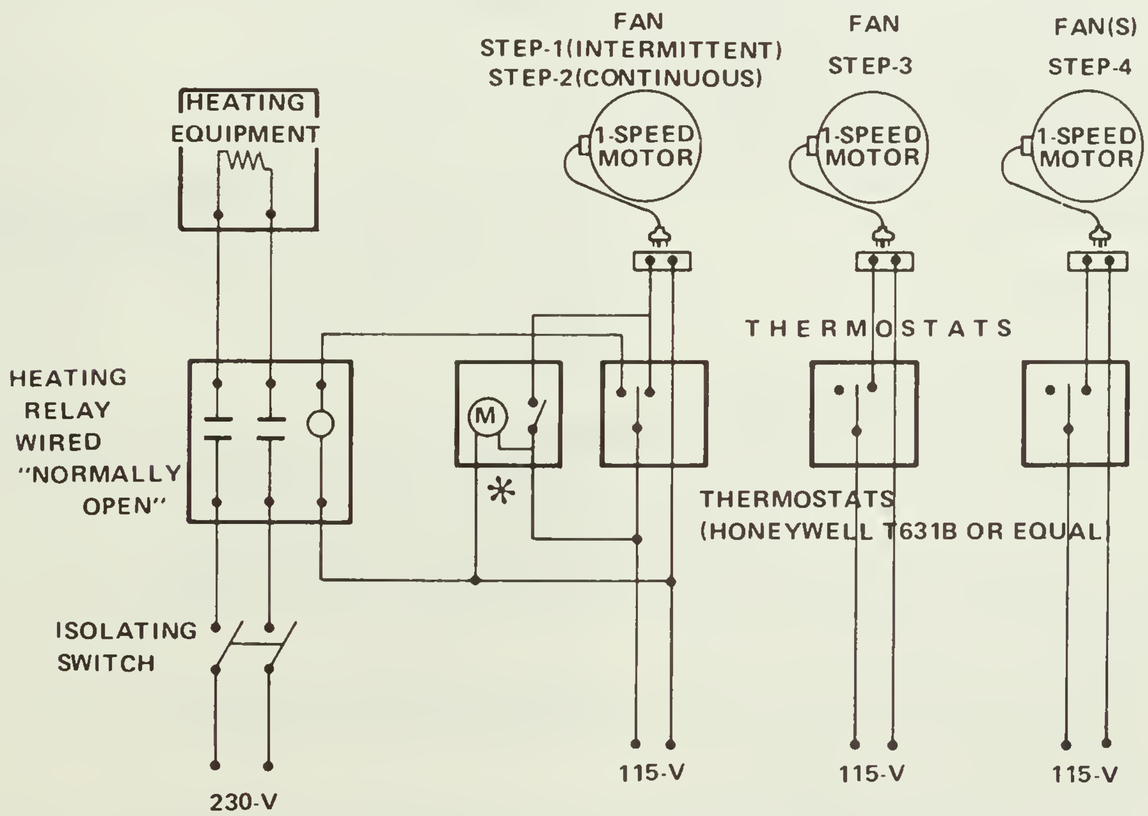


Figure 35. Interlocked heating/ventilating control with three single-speed fans, three ventilation steps.



* 10 – MINUTE CYCLE TIMER (PARAGON JW 10-0 OR EQUAL)

Figure 36. Interlocked heating/ventilating control with adjustable cycle timer to control intermittent Step 1 ventilation.

Figure 34 shows one way to wire such a system for a 2-speed step 1/step 2 fan. Only two-speed fan motors using a built-in isolation switch to disconnect the low-speed winding can be wired this way.

Figure 35 gives a wiring diagram where two separate fans are used to obtain steps 1 and 2. These two fans can be the same size, which is the surest way of obtaining Step 2 ventilation at twice the Step 1 rate. Then, with rising outdoor temperature, a third separate thermostat turns on Step 3 ventilation to maintain control of the barn temperature.

If electric heating is used, the loads will be too heavy for direct control by the interlocking thermostat, therefore, a relay is normally inserted in the heating circuit.

In practice, another problem is found in farrowing and weanling rooms where the Step 1 ventilation requirement is much too low for the smallest fan available. Over-ventilating with too large a fan will waste a lot of costly energy, so two choices are available: 1) buy the smallest fan and restrict its output by means of an adjustable baffle, but be careful not to throttle the fan to the point where the motor overheats, or 2) wire the smallest fan for controlled intermittent operation. In this case, it is better to settle for intermittent Step 1 ventilation than to over-ventilate the barn.

Figure 36 shows how to wire for intermittent Step 1 ventilation. First, if fresh air comes in via the attic, be sure the attic is well-ventilated. An adjustable 10-minute cycle timer is wired to cycle the first fan ON and OFF when the Step 1/Step 2 thermostat calls for minimum ventilation. Adjust the cycle timer ON period to give the required reduced ventilation rate. For example, to get 120 L/s average from a small fan rated 300 L/s, set the time clock for 4 minutes ON out of each 10-minute-cycle; $(4/10) \times 300$ L/s $= 120$ L/s. For Step 2 ventilation, the interlocking thermostat switches to bypass the time clock; this gives continuous ventilation (300 L/s, in this example) until the room temperature comes back down, the fan is switched to intermittent, and the heating comes back ON.

VENTILATION AND HEATING RECOMMENDATIONS FOR SWINE

Table 10 summarizes ventilation and supplementary heating recommendations for typical well-insulated swine units.

Note in Table 10 that the ventilation rates are stepped according to outside temperature conditions as illustrated previously in Figure 33. Three sets of fans with four ventilation steps are practical in the larger barn units such as breeding-gestation and growing-finishing. However the farrowing and weanling rooms are usually too small to justify more than two fans, so Steps 2 and 3 may be combined into one step.

Note also in Table 10 that the supplemental heat includes all heat sources other than the animals themselves. For example, if each farrowing pen is to have one 250 W heat lamp over the creep area, this will supply enough heat for good ventilation and temperature control down to about freezing temperature outside; more heat must be added to the room whenever outside temperature drops to below freezing.

If two classes of pigs share the same room (for example farrowing sows and weanlings) the total requirements for ventilation and heating can be based on the sum of the individual requirements of each group. Minimum room temperature in this case would have to be adjusted up to 21°C to suit the weanlings; this will increase the need for supplemental heat.

WHY EXHAUST VENTILATION?

Fans can be installed to either exhaust from or blow into a building. With intake fans, a distribution duct is required to spread the fresh air throughout the room, and the room will be at an air pressure slightly above the atmospheric pressure outdoors. This gives no particular advantage, but it has two important disadvantages: 1. air friction in the intake duct requires extra fan power and wastes some electrical energy; 2. warm moist air can be forced into cracks and cold air spaces within the walls and attic, causing damaging condensation within the structure.

For these reasons, exhaust (or 'negative pressure') ventilation is recommended for most farm building situations.

FRESH AIR INLETS AND AIR DISTRIBUTION

The exhaust fans and their controls represent only half of the ventilation system. The other important part is the air inlet, and this is the part which determines the movement and distribution of air within the room to be ventilated.

Fresh air distribution involves two distinct temperature situations. In fall, winter and spring, outside air is usually much cooler than the controlled conditions inside the building and fresh air must be directed well away from the pigs to avoid cold drafts at floor level. In the heat of summer, however, pigs crowded into the close confinement of the finishing pens can suffer terribly unless air currents can be directed to floor level to remove excess heat.

First, *the winter problem.* Refer back to Figure 31, and note that one kg of cold winter air occupies only 700 L,

TABLE 10. VENTILATION AND HEATING RECOMMENDATIONS FOR SWINE

Class of swine and type of housing	Winter minimum room temperature	Stepped total ventilation rates, L/s per pig				*Supplemental heat (watts per pig) at various outside design temperatures								
		Step 1 (winter continuous rate)	Step 2 (winter temperature control)	Step 3 (spring-fall temperature control)	Step 4 (summer temperature control)	-40°C	-34°C	-29°C	-23°C	-18°C	-12°C	-7°C	-1°C	+4°C
DRYSOW (180 kg average weight)														
– Breeding-gestation barn with group pens, 1.2 to 2.0 m² pen space per sow	10°C	2.5	5.0	15	60	103	65	28	0	0				
– Breeding-gestation barn with some individual stalls	16°C	2.0	4.0	15	60	107	75	49	23	1	0			
FARROWING SOW AND LITTER														
– Farrowing pen used for nursing to 3 weeks of age	**16°C	7	14		100									
– Farrowing pen used for nursing 6 weeks of age	**16°C	7	20		130	776	703	630	557	483	410	337	264	190
WEANLING PIG (7 to 25 kg)														
– Batch housing with all pigs about same age, 0.25 m² pen space per pig	21°C	0.7	1.4		15									
– Continuous housing with pigs ranging in size from 7 to 25 kg, 0.25 m² pen space per pig	21°C	0.9	1.9		15	79	70	61	52	44	36	29	22	16
GROWING-FINISHING PIG, SOLID FLOORS. (0.5 to 1.0 m² per pig)														
– Growers (23 to 57 kg)		1.2	2.5	5	20	84	69	54	40	28	16	4	0	
– Finishers (57 to 90 kg)	***16°C	2	4	8	32	100	82	63	47	29	15	0		
– Combined (23 to 90 kg)		1.5	3	7	25	88	72	56	41	26	15	0		
35% SLOTTED FLOORS (0.4 to 0.8 m² per pig)														
– Growers (23 to 57 kg)		1.2	2.5	5	22	48	37	25	13	2	0			
– Finishers (57 to 90 kg)	***16°C	1.5	3	6	40	56	41	25	12	0				
– Combined (23 to 90 kg)		1.5	3	6	30	50	37	23	12	0				

*Supplemental heat is based on pen space as indicated in this table, and on windowless construction with RSI-3.5 insulation in ceilings and walls and RSI-1.4 foundation perimeter insulation. For buildings with less insulation or more space per pig, supplemental heat should be increased for greater building heat losses. For buildings only partly filled, calculate supplemental heat on a building filled to capacity but reduce the winter ventilation.

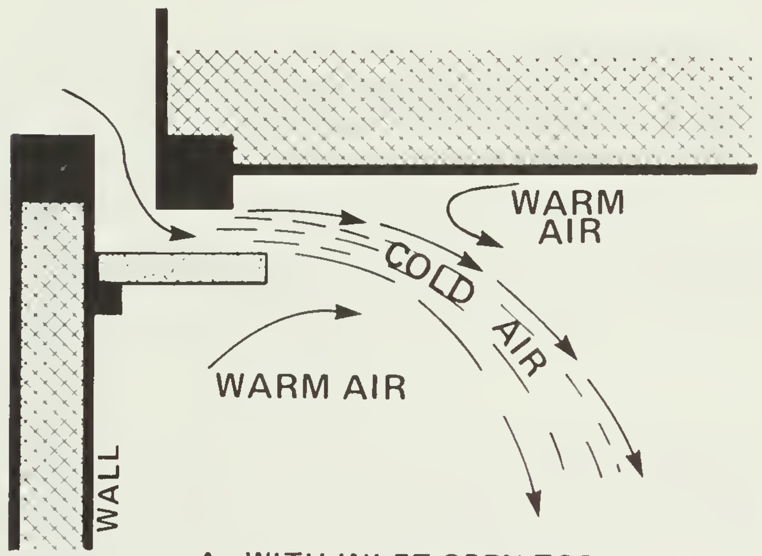
**16°C is a comfortable room temperature for the sow, but newborn pigs should have 27°C minimum. Provide a heated creep and gradually decrease creep temperature to 22°C as piglets grow.

***16°C is the recommended minimum room temperature where supplemental heat is added as required. If the barn is to be operated without any supplemental heat, set the Step 2 thermostat down to 10°C whenever cold weather is expected.

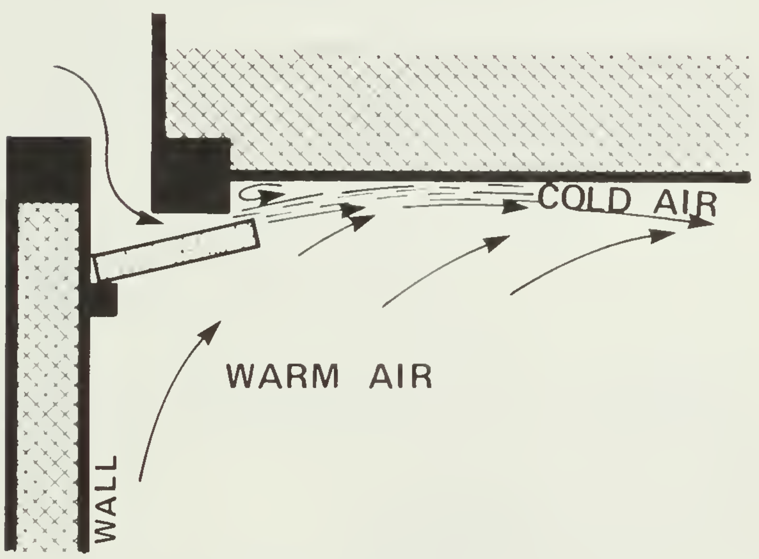
whereas the same kg of air warmed to 15°C inside the barn increases to 820 L volume.

To put this another way, cold air expands slightly and becomes lighter when heated.

Consider now what can happen when cold outside air is introduced into the warm air of the hog house. This cold air will be heavier than the surrounding warm air, therefore it sinks rapidly to the floor causing cold drafts, as shown in Figure 37A. Research indicates that to solve this problem, the cold air must be (i) directed along the ceiling (as far as possible above the pigs), and



A. WITH INLET OPEN TOO WIDE, LAZY STREAM OF COLD AIR SINKS TO FLOOR CAUSING COLD DRAFT



B. WITH INLET ADJUSTED CORRECTLY, HIGH-VELOCITY COLD AIR SWEEPS THE CEILING AND MIXES WITH WARM AIR

Figure 37. How the size of an air inlet slot affects the jet of cold air.

(ii) jetted forcefully into the room to promote rapid air mixing and prevent sinking, as shown in Figure 37B. An air jet velocity of 4 metres per second (m/s) through the inlet openings is just enough; 5 m/s is better. Also, the inlet air stream will stay up and move farther horizontally if it can skim along a smooth surface such as the ceiling, since it does not have to mix immediately with warm air at both upper and lower surfaces. Any small irregularities in the ceiling surface can 'unstick' the flow causing a down-draft; don't fasten things like electric wiring on the ceiling close to the inlet slots. And if corrugated metal is used for a ceiling, run the corrugations parallel to the intended air flow.

The amount of air coming through the inlets is controlled by the capacity of the exhaust fans. The velocity of the air jet however is controlled by the capacity of the fans and also the total area of *all* the inlet openings. To maintain the recommended velocity of 4 m/s for good mixing, air inlets must be adjustable; a good rule is to adjust the inlets to provide 1 m^2 of inlet area for each 5 000 L/s of ventilation. Automatic systems controlled by air pressure differential are available for adjusting the size of the inlet slots as the stepped ventilation switches up and down. Automatic systems are not fool proof, since an 'accidental' inlet (such as a door left ajar) can let all the air in at one end; then the automatic inlet closes, and most of the barn gets no ventilation.

Careful operators can make inlet adjustments manually with a winch and cable system. In cold weather, adjust manual inlet openings for the Step 1 ventilation rate, to give 4 m/s; this will increase to about 7 m/s when the fans increase to Step 2. For spring and fall weather where the Step 3 rate is required, open up the inlets to give at least 4 m/s velocity with fans in the lower step. For hot summer ventilation (at Step 4), it is usually best to change the inlet flap to direct fresh air towards the floor, except where small pigs could be exposed to direct drafts. Some improved slot inlets designed for easy adjustment are shown in Chapter VI, Figures 26 and 27 (pages 34 and 35).

Air movement in a room is influenced much more by the direction and speed of the incoming fresh air than by the location of the exhaust fans. Figure 38 shows the results of smoke tests in a typical building with side wall inlet slots adjusted correctly for winter ventilation as in Figure 34B. Note in Figure 35 (Section) that the fresh air entering at 5 m/s has enough energy to turn the room air over slowly in two loops, meeting near the center. This slow turning of the air is very important to prevent the development of cool or warm layers and to supply enough fresh air to all the animal pens.

Figure 38 was drawn for a building about 10.8 m wide with a 2.7 m ceiling. Note that the two opposite vor-

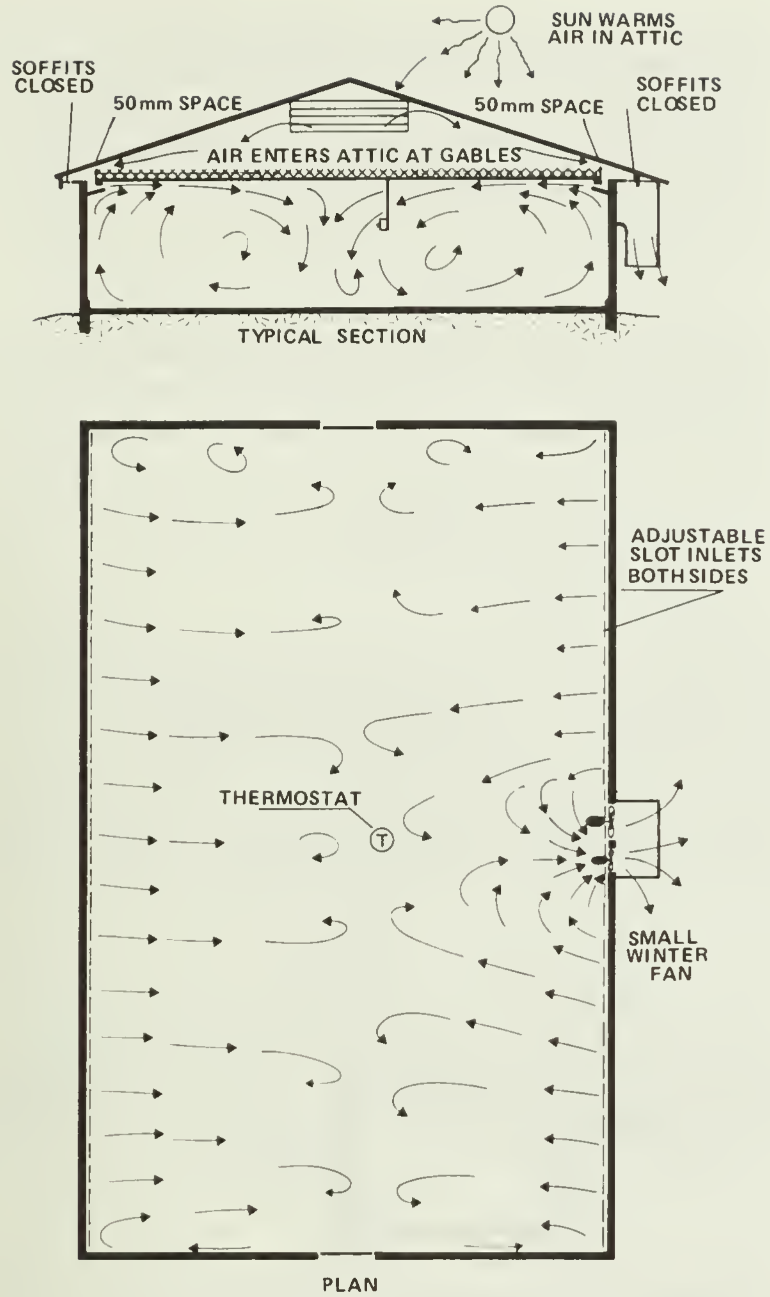


Figure 38. Air circulation patterns with sidewall slot inlets adjusted for fall, winter, and spring ventilation.

tices of air are each about 5 m wide. If the inlet slot were open on *one sidewall only* the pattern would change somewhat, since the single slot would not be capable of turning the entire room air over in a single turn. A single inlet slot on the wall opposite the fans can however give fairly satisfactory circulation in rooms up to about 6 m wide (farrowing rooms, for example).

Note in Figure 38 (plan view) that the area directly influenced by the exhaust fans is relatively small; with properly designed inlets the location of exhaust fans is relatively unimportant.

Figure 39 shows the same building as Figure 38, but with air inlet flaps changed to circulate fresh air down the walls for hot weather. This is useful for dry sow barns and growing-finishing barns since larger pigs suffer more from heat. Note here that the warm air circulates in the opposite direction to that in Figure 38 (section). Research shows that this will move air faster at floor level and prevent hot spots (ref. 10).

Figures 38 and 39 show another useful ventilation principle. In cold weather, fresh air comes to the inlet slots by way of the attic; this lets the sun preheat the inlet air slightly to help the heat balance. On bright sunny days the air may be warmed 1 to 3°C. This will not help at night when the heating load is highest, but it can help to dry out a swine building having insufficient supplemental heating capacity.

In summer, attic temperatures under a hot roof can rise considerably above the outside temperature. So fresh air (Figure 39) is let in through the eaves by opening a series of hinged soffit panels. The area of these wide soffit openings is much greater than the narrow openings from the eave to the attic, to ensure ventilation directly from outside.

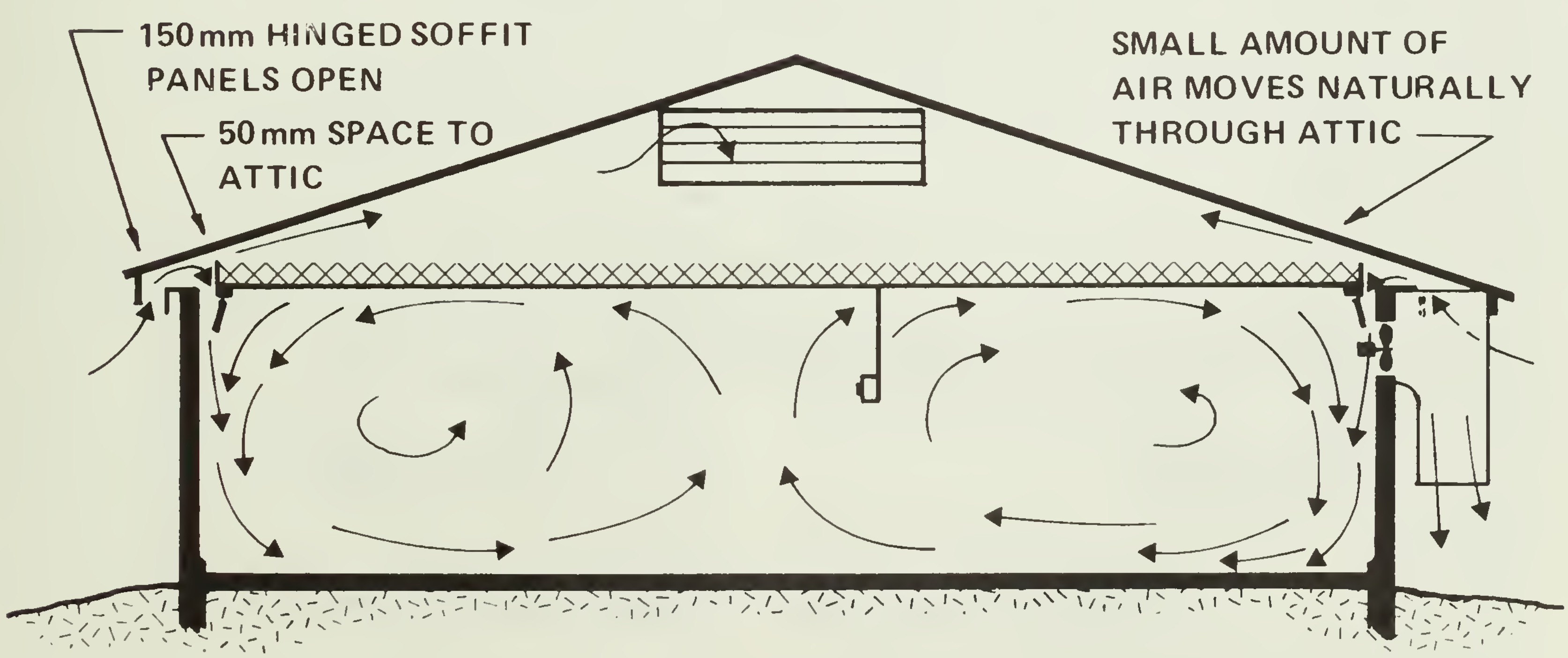


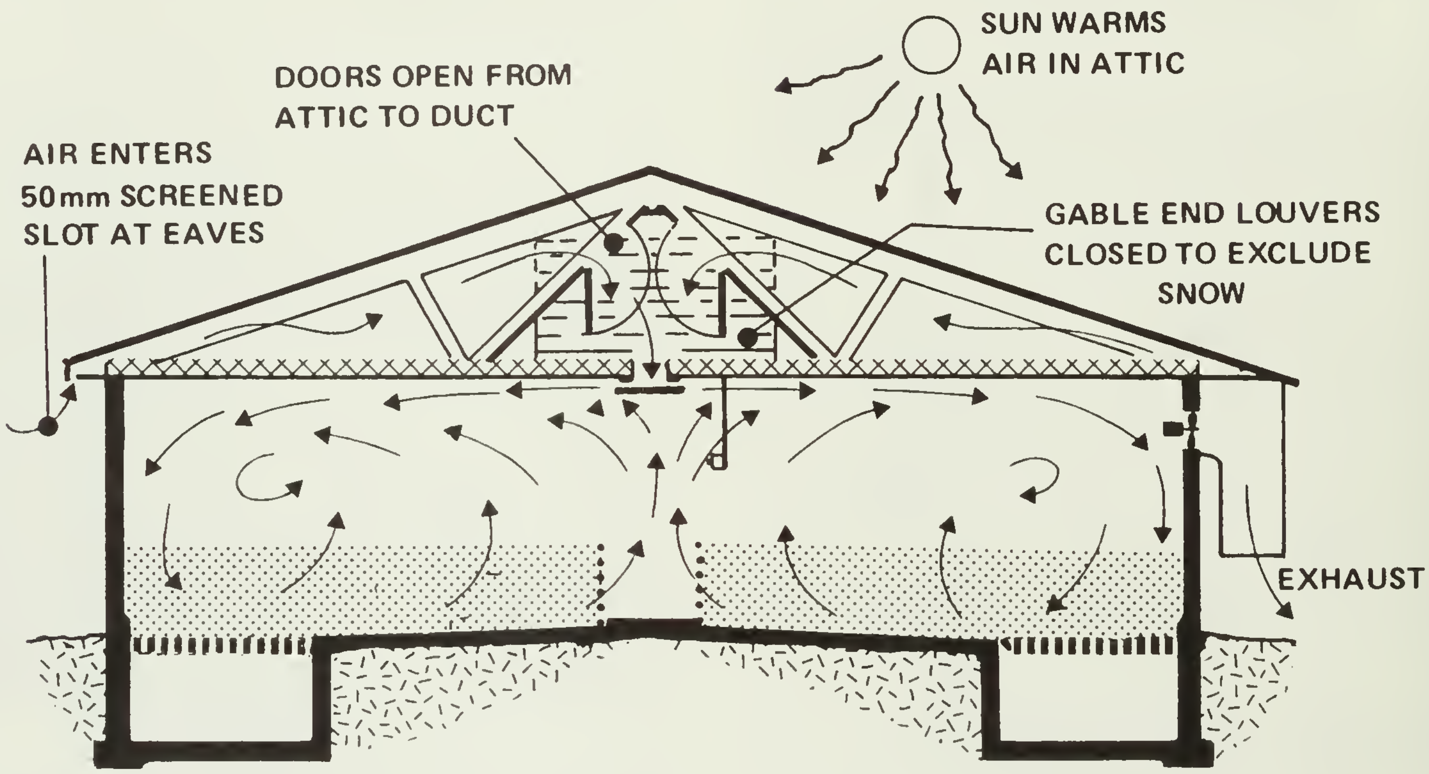
Figure 39. Air circulation patterns with sidewall slot inlets changed for emergency heat stress in hot weather.

RELATING FRESH AIR DISTRIBUTION TO PEN LAYOUT

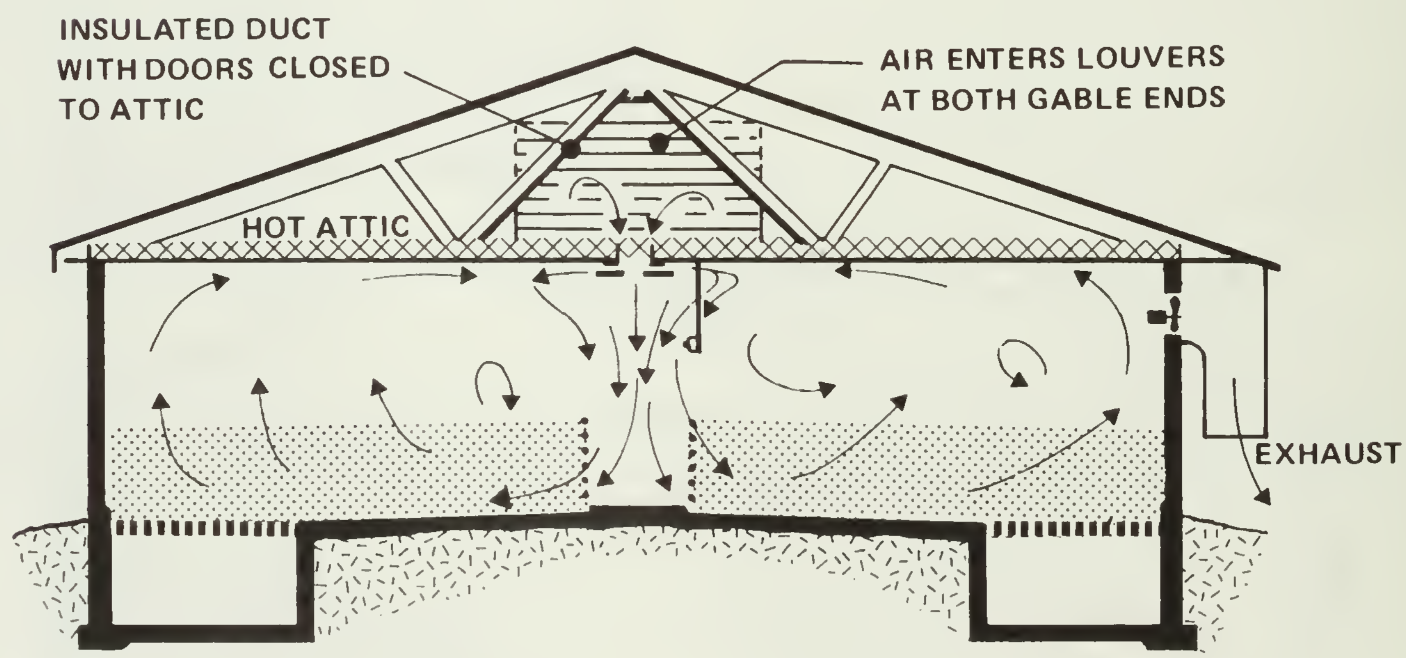
Fresh air inlets are not always best at the outside walls. Consider for example a growing-finishing building with slotted floors adjacent to the walls and a feeding passage at the center. The high concentration of animals in such a building requires special ventilation in hot weather.

Consider the effect of using vertical inlets discharging down the walls as in Figure 39. The strong air current down the walls encourages pigs seeking relief from the heat to lie on the slotted dunging area, and the pigs get dirty. Another problem with this inlet arragement is that the stream of fresh air is carried first through the slotted floor into the liquid manure trench and the air is contaminated with manure gases before the pigs receive it.

Figure 40 shows a center air inlet designed to overcome this situation. In Figure 40A the winter fresh air comes through the attic into the center slot and is



A. NORMAL OPERATION WITH INLET SLOTS DIRECTED HORIZONTALLY AT CEILING



B. EMERGENCY HOT WEATHER OPERATION WITH INLET SLOT DIRECTED DOWN TOWARDS RESTING AND FEEDING AREA OF PENS

Figure 40. Hog grower-finisher with slotted floors and adjustable center air inlet.

directed both ways along the ceiling. This sets up a turning of the air which is aided by the heat rising from the animals lying on the solid floor. To assist the circulation, add supplementary heat when required by heating the floor or the air near the center of the building.

Figure 40B shows the inlet opened to discharge air straight down for emergency heat stress in hot summer days. With steel mesh or other open material for the pen front gates, this fresh air circulates first into the sleeping area to encourage pigs to lie at the clean end of the pens. Construction details for this inlet are shown in Chapter VI, Construction, Figure 27.

Never draw attic air in summer; on a hot sunny day the ventilated attic of a finishing barn can be 2 to 4°C *hotter* than outside! Build a big air duct insulated with 50 mm polystyrene board nailed to truss webs in the attic space. Supply fresh outside air to *both* ends of this duct, through big tip-in doors with bird screening. Close these doors in winter to keep out snow.

SPECIAL INLET PROBLEMS IN WINTER

All the preceding discussion of fresh air distribution applies where the inlet velocity is *at least* 4 m/s. At low winter ventilation rates the inlet flaps must be very accurately fitted to make slots small enough to give this controlled inlet air speed.

With high-density housing such as growing/finishing pigs at about 1.0 m^2 of floor space per pig, the problem is not difficult. In a barn 10.8 m wide, each metre of barn length holds at least 10 pigs. At the step 1 ventilation rate of 1.5 L/(s · pig), this gives 10 pigs × 1.5 L/(s · pig) = 15 L/s ventilation. To give 4 m/s at the inlets, two continuous inlet slots would have to be adjusted down to:

$$\frac{15 \text{ L/s}}{4 \text{ m/s} \times 2 \text{ slots}} = 2 \text{ mm slots}$$

Rigid polystyrene inlet flaps stiffened with *straight* strips of galvanized sheet steel angle as shown in Figures 26 and 27 can be adjusted down to 2 mm; with poorly-made inlets, this accuracy is impossible.

Winter air distribution problems are more difficult in low-density housing such as farrowing or weanling barns, with relatively low ventilation rates. Here it will be necessary to reduce the length of inlet slots into each room. Possibly use one inlet slot instead of two, or break the inlet into short lengths separated by spaces with no inlet. Always check to be sure the total inlet slot length and minimum slot opening are suitable for the step 1 winter ventilation.

For critical ventilation such as farrowing barns and elevated weaner cages, where temperature variations and drafts could be serious, it is better to preheat the fresh air almost up to temperature in an adjacent room or hallway. Then use a baffled inlet through the wall or ceiling into the pig room. Check with a portable thermometer and some smoke to be sure the temperature is uniform and that there are no cold air leaks around doors and other joints. Another future possibility is to use solar heating in winter to pre-warm the air in the service hallway; for this, consider running the swine barn east-west, with a solar radiation collector built into the south-facing exterior wall of the hallway. Figure 20 (page 28) shows one such plan with a suitable service hallway along the south side of the farrowing area.

INLETS, FANS AND STATIC PRESSURES

Up to this point little mention has been made of the forces that cause ventilation air movement. With exhaust fan ventilation, fans suck air from the room causing a reduced air pressure which is below the atmospheric pressure outside. Then outside air slips through any openings, large or small, to try to equalize the two pressures.

The importance of maintaining high inlet velocity has already been emphasized. Inlet velocity however is directly related to the pressure difference, outside-to-inside. This pressure difference should be measured in Pascals, but for the very low pressures encountered in ventilation, measuring the height of a water column in a transparent U-tube is more convenient. Measure the water column height in mm, then convert to Pascals (1.0 mm = 9.8 Pa). Figure 41 shows how static pressure is measured and the relation between static pressure and inlet velocity. The small glass U-tube partly filled with colored water gives a direct measurement of the pressure reduction inside the building. Figure 41 shows, for example, that to produce the 4 m/s minimum inlet velocity recommended for good mixing, the static pressure must be about 1.3 mm of water.

What this suggests is that an inexpensive U-tube or inclined-tube water manometer can be installed to monitor the ventilation system. Run a small air tube into the attic instead of outdoors as shown, to eliminate wind pressure effects. If the manometer reads at least 1.3 mm of water, the inlets are giving the critical 4 m/s; if not, either the inlets need adjustment, or the building has too many air leaks.

Of course, the higher the static pressure, the harder the fans must work to remove air. The fans must do more than just draw air through the inlets. See Figure 39. This shows the pressure effects of a 30 km/h headwind blowing against the exhaust side of the building. If this fan blows straight into the wind without protective

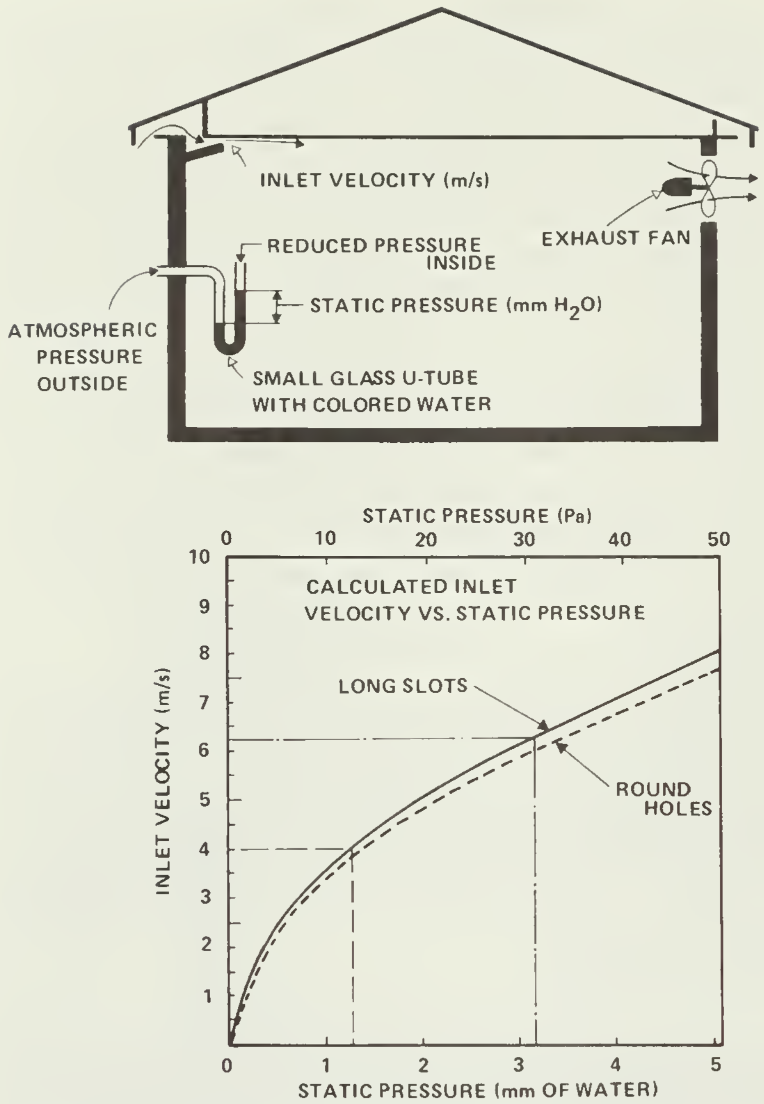


Figure 41. Measuring static pressure, and its relation to the velocity of the inlet air air stream.

hood as shown, the fan would have to put out 3.2 mm of static pressure just to open the fan louvers. And another 2.3 mm of suction would have to be developed to draw air to the inlet slot through the leeward wall.

Thus the total pressure at the fan (without fan hood) could be 2.3 (leeward suction) + 1.3 (inlet slot) + 3.2 (headwind) = 6.8 mm. This is dangerously close to the point where many ventilation fans stop moving any air, and 60 km/h winds develop forces four times as high!

One possible answer would be to place exhaust fans in a leeward wall. Unfortunately, however, the wind blows from many directions and the leeward wall today may be the windward wall tomorrow.

A better solution is to hood all inlets and outlets so that air enters and leaves the building vertically (perpendicular to the wind flow). Fan hoods should turn down a full 90° as illustrated and should extend at least 300 mm below the mid-height of the wall. Inlets can be partly sheltered by the eave structure as shown. This also helps to keep out snow, especially if the eave slot is placed just behind the face board, not against the wall.

Wind can reduce ventilation rate by interfering with fan output, or it can cause overventilation. Where unprotected inlets are open at both walls, wind can force air through a building even with the fans stopped. This can be a serious problem in cold weather, especially with small pigs, where ventilation requirements are small. Figures 38 and 40 show two methods of using the attic space to cancel the winter wind effect.

OTHER SYSTEMS

Ventilation systems discussed up to this point all use exhaust fans (Figure 43) to reduce the room pressure a little below the outside atmospheric pressure. This has the advantage that small cracks in the structure act as fresh air inlets, preventing moisture from penetrating the spaces within the walls and ceiling.

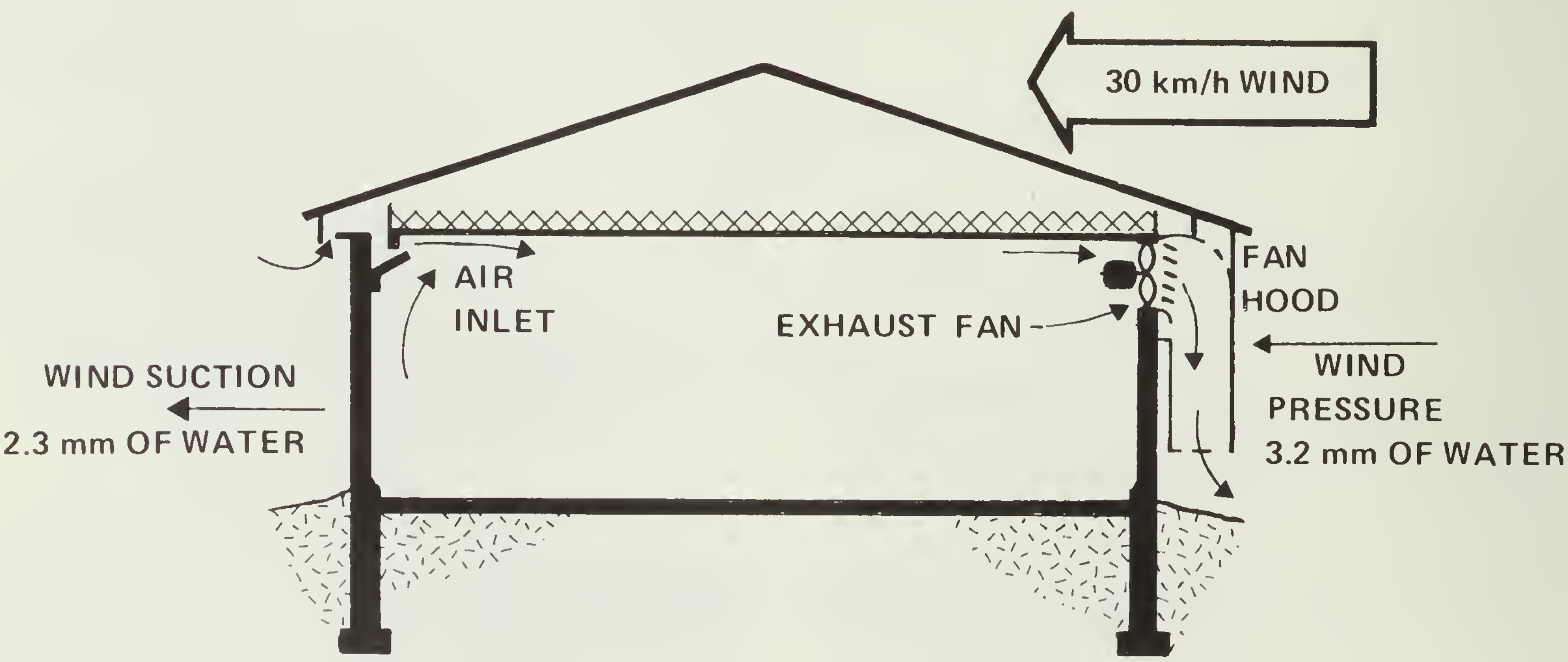


Figure 42. Pressures caused by headwind on a typical swine building.

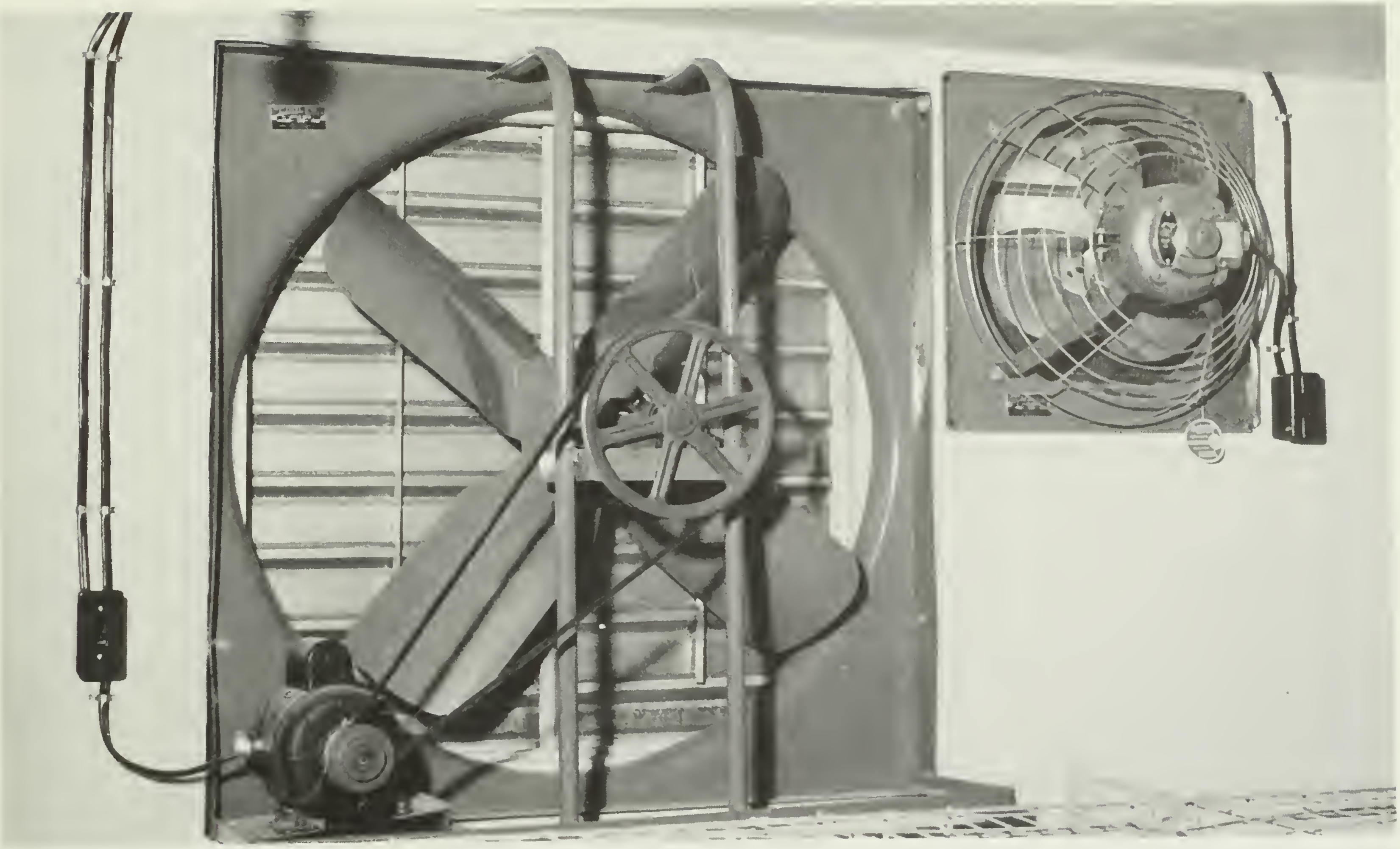


Figure 43. Two-fan exhaust system for stepped ventilation. The small fan is two-speed direct-drive for good winter performance against headwinds. The large fan is the low-speed belt-driven type for high output per watt in hot weather. Photo courtesy of Ontario Hydro.

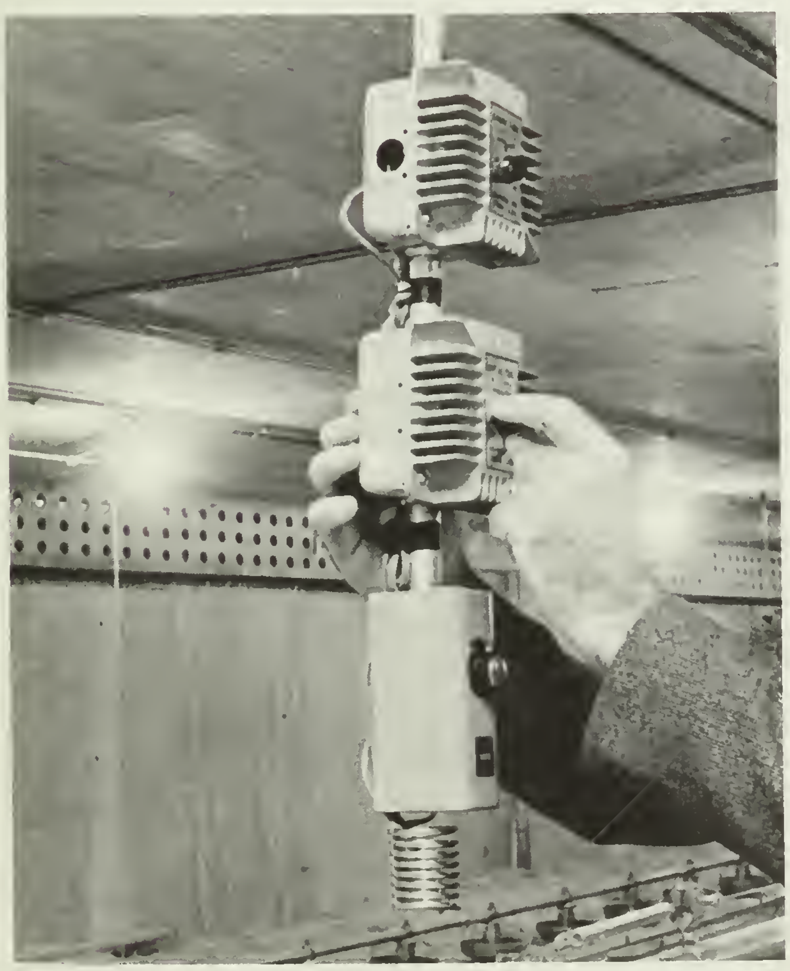


Figure 44. Modulating electronic fan control for variable-speed fan motors.

Manufacturers are now offering a variety of ventilation equipment designed to make installation in existing barns easier, and to improve the control of air flow to the animals. Figure 44 shows a modulating control and low-limit cutoff thermostat. When connected to a special voltage-sensitive fan motor, this electronic system can vary the fan speed from about 25% to full capacity, depending on manual adjustment or on temperature changes. These fans when throttled down to minimum speed are much more sensitive to headwind pressures than fans running at full rated speed. Headwinds can cause problems such as motor burnout and unpredictable ventilation rate unless the fan is properly protected with a weather-hood (Figure 42).

Other recent developments include several powered inlets and air blenders, illustrated in Figures 45, 46 and 47. An advantage of these recirculating air blenders is that good air distribution can be maintained even at low ventilation rates. This is possible because these systems recirculate air to the inlet openings at a high constant rate, but fresh outside air is blended into the recirculated air at a variable rate depending on outside temperature. This eliminates the need for frequent adjustment of the winter air inlets to maintain the required

inlet velocity for good mixing. Powered air blenders require more electric energy than small exhaust fans for winter ventilation. However, in winter a large part of this energy is not wasted but returned as supplemental heat. Each of these units should be installed according to the manufacturer's recommendations.

CHOICE OF ENERGY FOR SUPPLEMENTAL HEATING

Table 10 (page 45), gives an indication of the amount of supplemental heat required for good temperature control and ventilation in modern swine buildings. The methods of adding the required heat however depend on many factors. Electric heating is popular for local heating such as baby-pig creeps and in situations where separate control of heating is required in many small areas (zone control). On the other hand, large swine operations with big heating requirements in each pig area may be able to justify the extra initial costs of a fuel-burning central heating plant plus a fire-resistant heating equipment room.

This choice will depend on the relative local cost of electrical energy versus fuel. For example, 1 L of No. 2 furnace oil at 22¢ can burn to give about 11.0 kWh of energy. Small domestic furnaces and hot water boilers suitable for heating swine buildings utilize only 60% to 70% of this heat; the rest is lost up the flue.

Taking this efficiency at 60%, 1 L of oil gives 60% X 11.0 kWh = 6.6 kWh of useful heating ener-

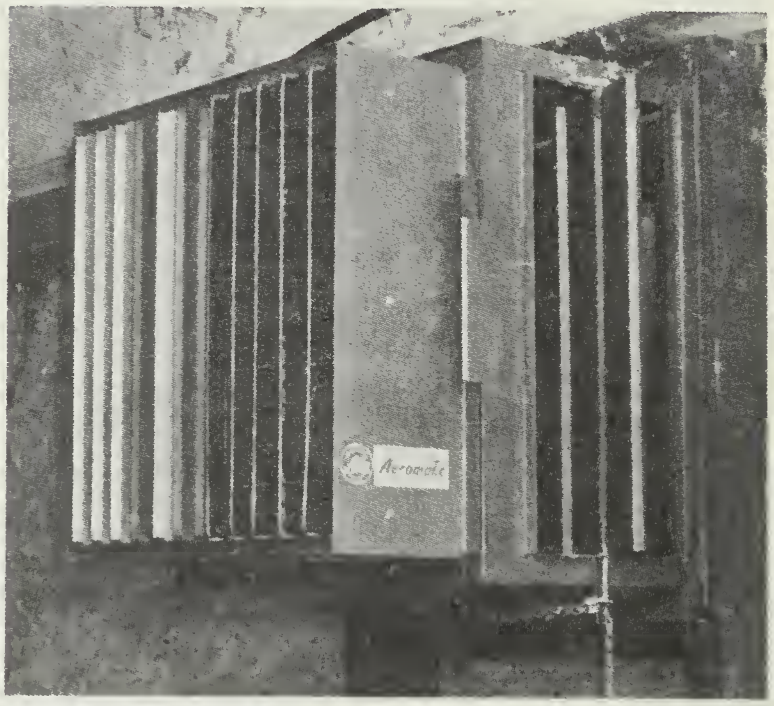


Figure 46. Powered air blender with adjustable directional louvers for air distribution. This wall-mounted unit requires no inlet slots or ductwork, but uses two additional thermostat-controlled exhaust fans to control ventilation rate.
Photo courtesy of Aston Industries, Inc.

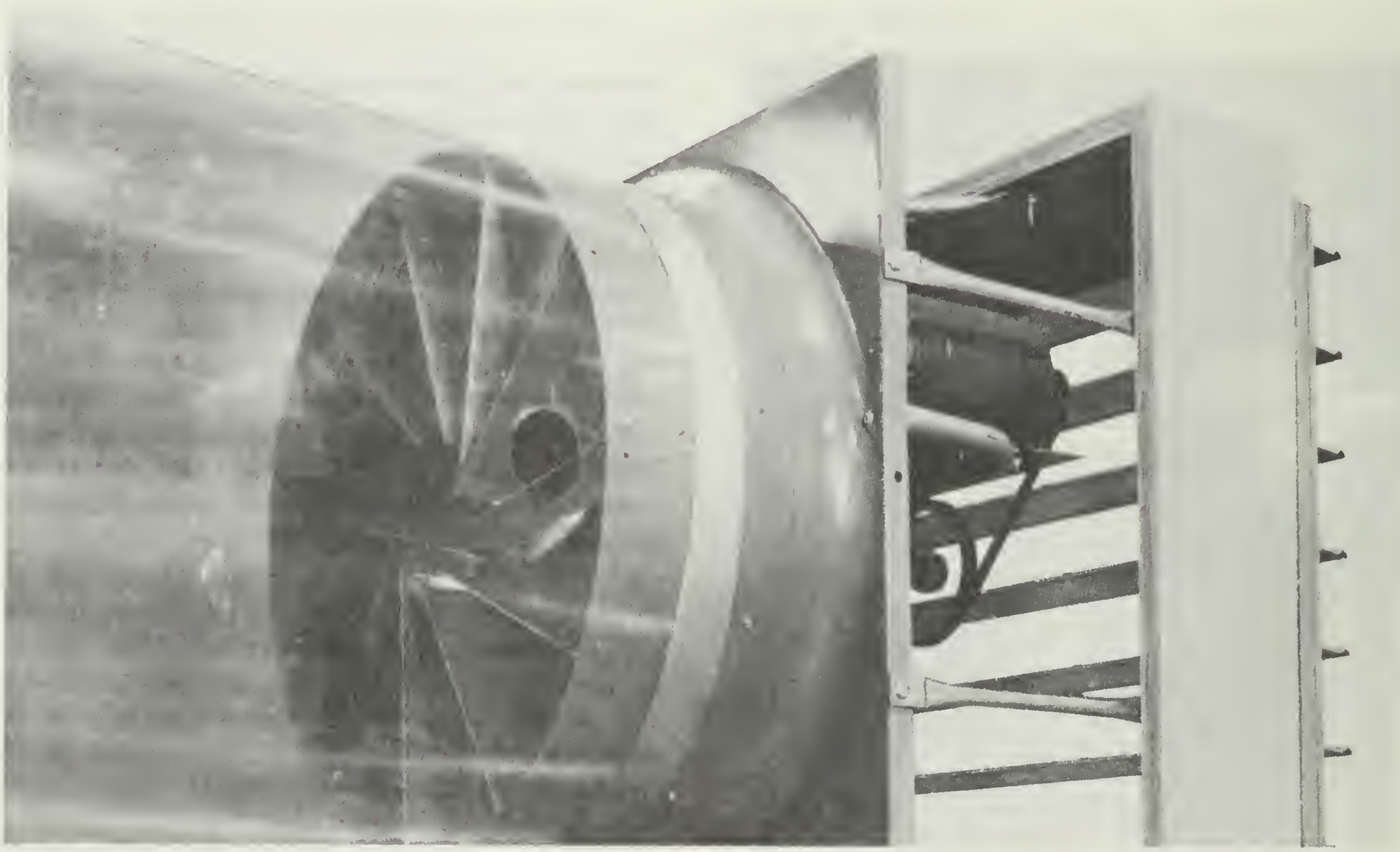


Figure 45. Powered air blender with perforated plastic tubing for an air distribution duct. This system requires additional air intakes and exhaust fans for maximum summer ventilation.

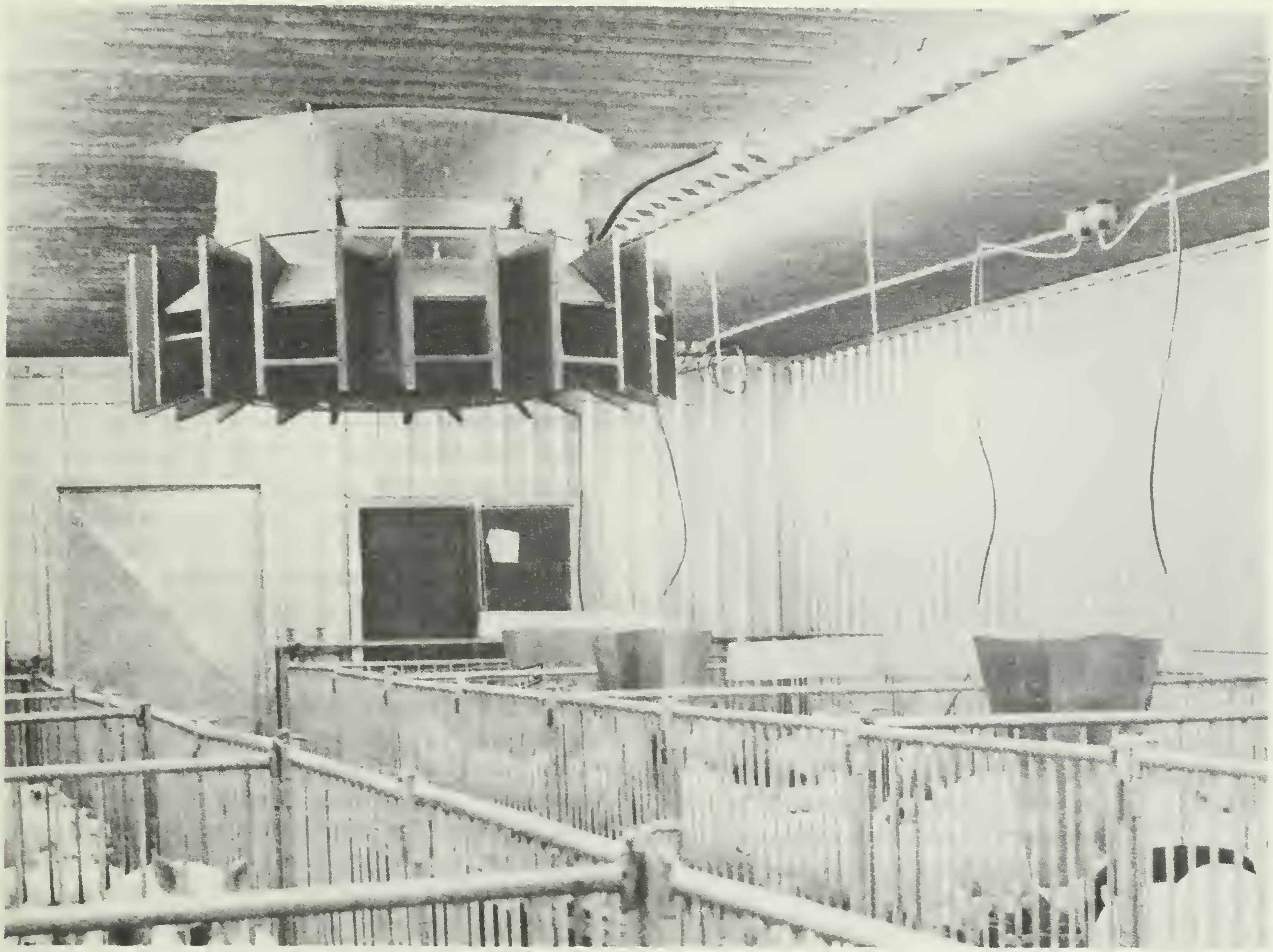


Figure 47. Powered air blender, ceiling-mounted. This unit combines air intake and exhaust in the same vertical stack, and automatically adjusts the proportion of recirculated air for temperature control. Photo courtesy of Fristamat Ltd.

gy. In other words, 22¢ buys 'oil' energy equivalent to electrical energy costing 6.6 kWh X 5¢/kWh = 33¢. Substitute your own figures for the above prices of oil and electrical energy. Allow also for the fact that fire insurance rates may be higher with a fuel-burning heating plant.

METHODS OF ADDING HEAT

Three methods are in common use — radiant heating, floor heating, and space heating. Radiant heating and floor heating are best for warming a small local area such as the baby-pig creep or the sleeping area of a weanling pen, where it is not necessary or desirable to heat the entire room (space heating). In farrowing rooms it is common to use space heating in addition to local floor or radiant heating in the baby-pig creeps. This makes it possible to have about 15°C room temperature for good ventilation and sow comfort plus extra warmth for baby pigs.

Radiant heating can be 250-watt pyrex-glass heat lamps properly installed (see Figure 48) or the newer quartz-tube type radiant heaters (see Figure 49). For farrowing pen baby pig creeps, provide about 250 watts of radiant heat for each creep area, or 500 watts for two creeps side-by-side. Propane-fired combustion type radiant heaters are available but are not recommended because of fire hazard.

The heat from electric radiant heaters is usually adjusted by raising or lowering the suspension chains. This adjustment serves the needs of a growing litter of piglets but it does not provide a means of economizing when less heat is needed. Some of the quartz-tube radiant heaters have built-in thermostats to reduce energy wastage.

Figure 50 gives electric or hot water heating requirements for insulated floor slabs. Insulation of the heated slab perimeter is important if slab temperature is to be

Figure 48. A protected heat lamp provides warmth for a new litter. Note the guarded reflector which is secured by chain to the ceiling. The power cord is plugged into an overhead ceiling outlet and adjusted so that it will pull out if the lamp should fall.

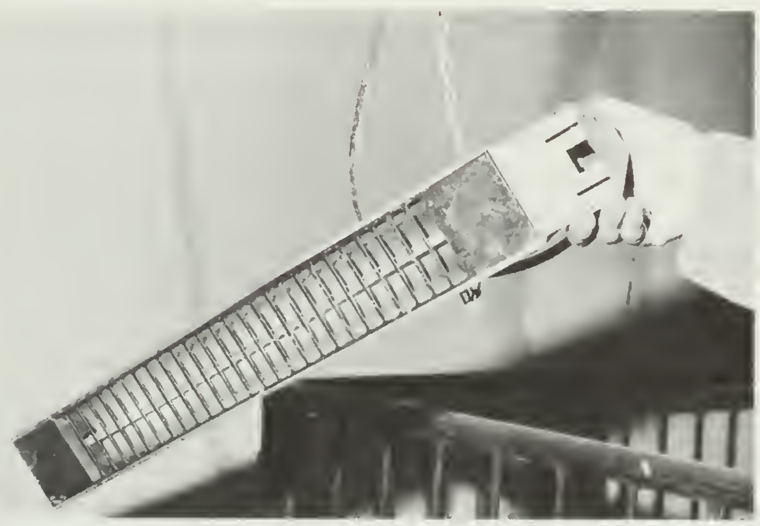


Figure 49. Quartz-tube electric radiant heater.

maintained, since concrete will conduct heat away horizontally into the surrounding floor area.

Underfloor hot-water piping is an excellent way to add heat in weanling sleeping areas and other situations where floor heat is required in long strips. Underfloor pipe may be steel, medium-density or high-density polyethylene, but in all cases the header pipes and the connections to the circulating water heater should be steel pipe. With polyethylene pipe, be sure to use a water temperature-pressure combination that the pipe can stand without bursting. For example, ordinary medium-density polyethylene pipe is safe only up to 49°C and 138 kPa pressure, and the higher the temperature the lower the pressure. Better grades of plastic pipe are available for up to 93°C and 689 kPa.

Figure 51 shows an automatic electric water heating system for circulating heated water to floor piping (as in Figure 50), or to wallhung pipe or fin-tube radiators (Figure 53). This electric circulating heater may be replaced by a hot-water furnace if preferred. The furnace must be isolated in a nearby heating room constructed to provide at least 3/4-hour fire separation. Isolating the furnace room also prevents exhaust ventilation fans in the barn from causing back-drafts down the furnace flue. Detailed design of a fueled heating system is beyond the scope of this bulletin.

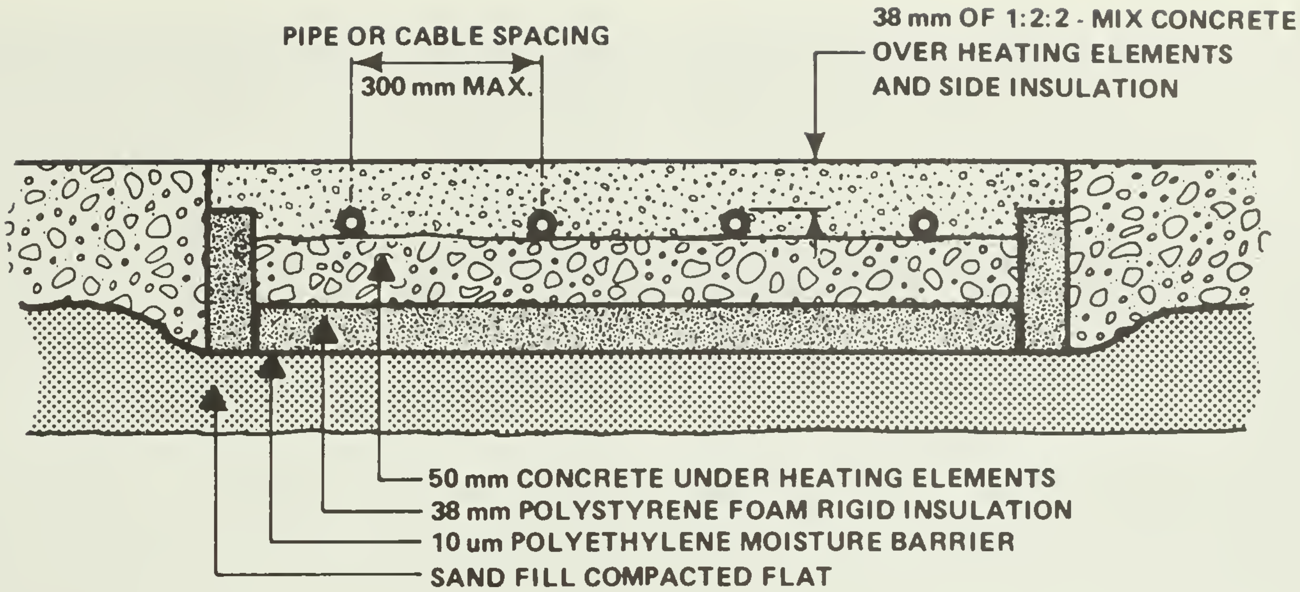
Space heating may be required for good ventilation in growing-finishing buildings, and in combination with radiant or floor heating in farrowing and weanling barns. Use Table 10 as a guide to total heating requirements and provide space heating to make up the difference where the local radiant or floor heating is not adequate.

Add small amounts of space heating by fan-forced electric heaters (Figure 52), available in various capacities from 1.0 kW. They can be located to direct warmed air into the cold air stream coming from the fresh inlets. Locate as far as possible from the exhaust fans to minimize heat wastage. Elements of the "black heat" type are preferred.

Domestic hot-air furnaces have been used for space heating. There are difficulties however if the air is dusty, especially with floor feeding or dusty bedding, as dust quickly blocks the filters in the furnace cold-air return. Hot-air furnaces have been used successfully for relatively dust-free pig areas (slotted-floor pens for example) by modifying the filter chamber to provide three to four times the normal filter area. This is practical where one furnace can serve a large common area, but not where separate areas are to be isolated for disease control.

Remember that hot-air furnaces, like other combustion heating devices, must be located in a separate room so that the flue gases are not sucked back down the flue by the ventilation fans.

It is possible to use a small hot-air domestic furnace to preheat air to about 10°C in a furnace room or service hallway, then draw this preheated air into an adjacent



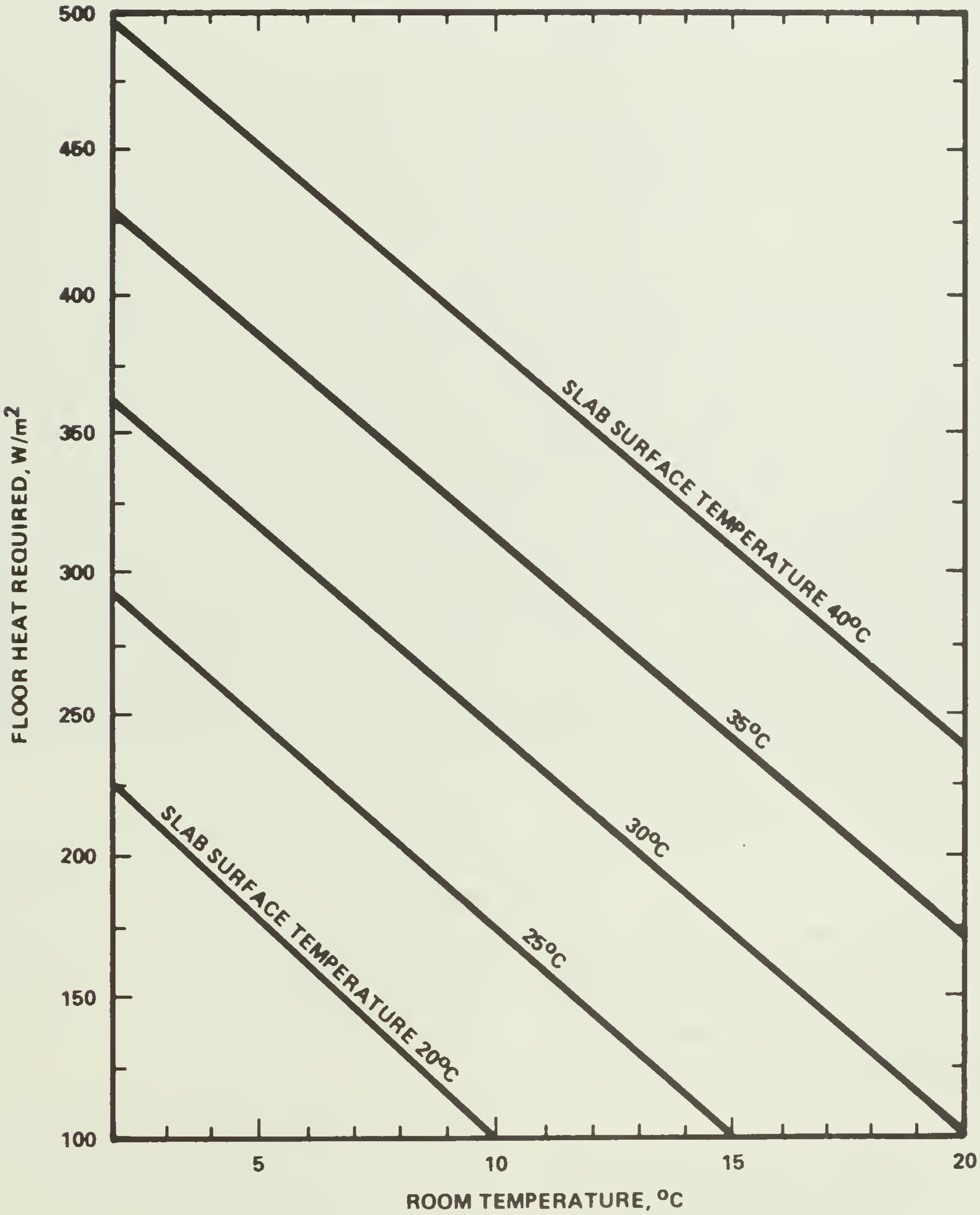


Figure 50. Temperature of heated concrete floor slab with 38 mm insulation.

swine area where heat lamps or other heat sources can finish the heating. Provide a large fresh air intake from outdoors into the preheat room; this ensures that furnace flue gases won't be drawn back into the furnace room. The outside air intake should be protected with a screen and weatherhood to keep out rodents, birds, rain and snow. The insurance company may insist that the air-duct from preheat to swine areas should have an automatic fire damper to close the duct in case of fire.

If only one swine area is to be preheated, the furnace control thermostat can best be located in the swine room (see Figures 34, 35 and 36, Interlocked heating/ventilating controls); this ensures that the furnace won't cycle too frequently. If several swine rooms are to be preheated from the same preheat room, the heating thermostat must be located in the preheat room. With hot-air heating, unless the preheat room is very large, its temperature will fluctuate too rapidly, causing excessive furnace cycling. Electric space heaters or hot water heating work better in this case. With electric space heaters, re-connect the heater fans to run continuously and control only the heating coils by thermostat. With hot water heating, consider the problem of the water pipes freezing in case of heating failure.

Hot-water space heating is very good for dusty swine barns and especially where several rooms are to be heated from a central heating room. Heating can be from an electric circulating water heater or a domestic hot-water furnace. The system is like hot-water heating for homes except that smooth steel pipe painted flat black replaces the radiators or finned tubing. Ordinary domestic radiators and finned tubing are not very suitable for swine barns because they are hard to clean and not durable enough for pigs.

The black steel pipe radiator may consist of one or more pipe loops hung on a wall by sliding brackets for pipe expansion. Piping connections and the automatic water make-up system in the heating room are similar to Figure 51. One thermostat-controlled circulating pump controls heat to each room and a master control built into the water heater maintains water temperature.

Figure 53 shows how hot-water space heating can complement the ventilation system. With the pipe radiator hung under the inlet slot as shown, a rising current of air from the radiator joins the cold fresh air from the inlet slot at the ceiling. This gives good air circulation without drafts or cold spots.

Complete information for design of a hot-water heating system is beyond the scope of this publication, but Figure 54 gives some basic information for selecting pipe size and temperature.

Water must be circulated through the pipe radiator fast enough to provide good water-to-pipe heat transfer. A water velocity of 1.0 to 1.5 m/s gives good heat transfer without requiring unreasonable pump capacity. Water temperature drop through the radiator length should not exceed 5°C; a single or double loop of pipe thus gives fairly uniform radiation from both outgoing and return legs. Start design by determining the heat required, then assume a radiator pipe size and determine the total length of radiator loop (usually controlled by the length of the room to be heated). Select from Figure 54 a pipe surface-to-air temperature difference required to radiate enough heat, calculate the hot water flow rate required to supply that amount of heat at not over 5°C temperature drop, check to make sure the velocity is between 1-1.5 m/s, increase or decrease the pipe size if required, and check through again with the revised pipe size.

SUMMER COOLING FOR GROWING, FINISHING AND BREEDING PIGS

Refer back to Tables 1 and 2, page 5 to see how pigs (particularly larger ones) suffer from excess heat. Research indicates that under Canadian climatic conditions cooling by refrigeration to maintain pig comfort is not generally economic. Evaporative cooling of the incoming fresh air by water sprays or wetted filters can reduce the temperature considerably if the initial air outside is very dry, but in most areas of Canada humidification to reduce temperature does not make the pigs any more comfortable.

Sprinkler cooling of the pigs by a coarse water spray however can be effective (Ref. 14), and the equipment is so inexpensive that one 2-week heat period could pay for the installation, particularly with pigs over 50 kg. This is the equivalent of keeping children cheerful in hot weather by letting them run through the spray from a lawn sprinkler. Coarse droplets of water wet the skin, and evaporation of the water at skin temperature removes excess body heat more effectively.

Figure 55 gives details of installation. Water from the pressure supply system is controlled by a 115-volt solenoid valve (normally closed with power off) and a thermostat connected to open the valve on temperature rise. Set the thermostat to start sprinkling at about 25°C but watch the behavior of the pigs to make sure they want cooling at the set temperature, and adjust accordingly.

Since unevaporated water can quickly fill the liquid manure storage, connect an inexpensive 30- or 60-minute timer in series with the thermostat. With this the operator can preset the 'on' time, from a few seconds up to the full cycle time. About one minute 'on' time per 60-minute cycle has given best results

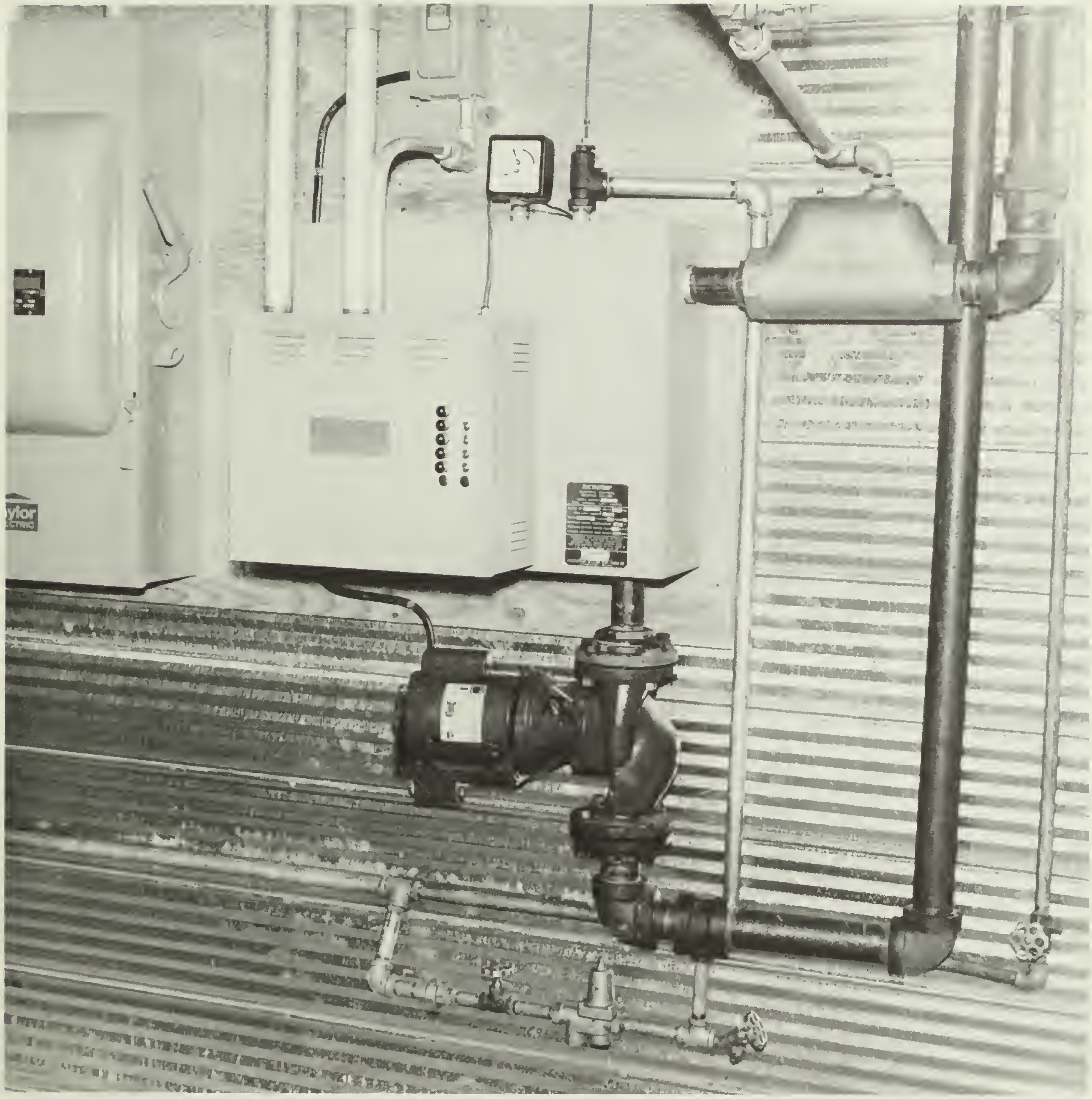


Figure 51. Electric circulating water heater system for floor slab heating or space heating with wall-hung smooth steel pipe.

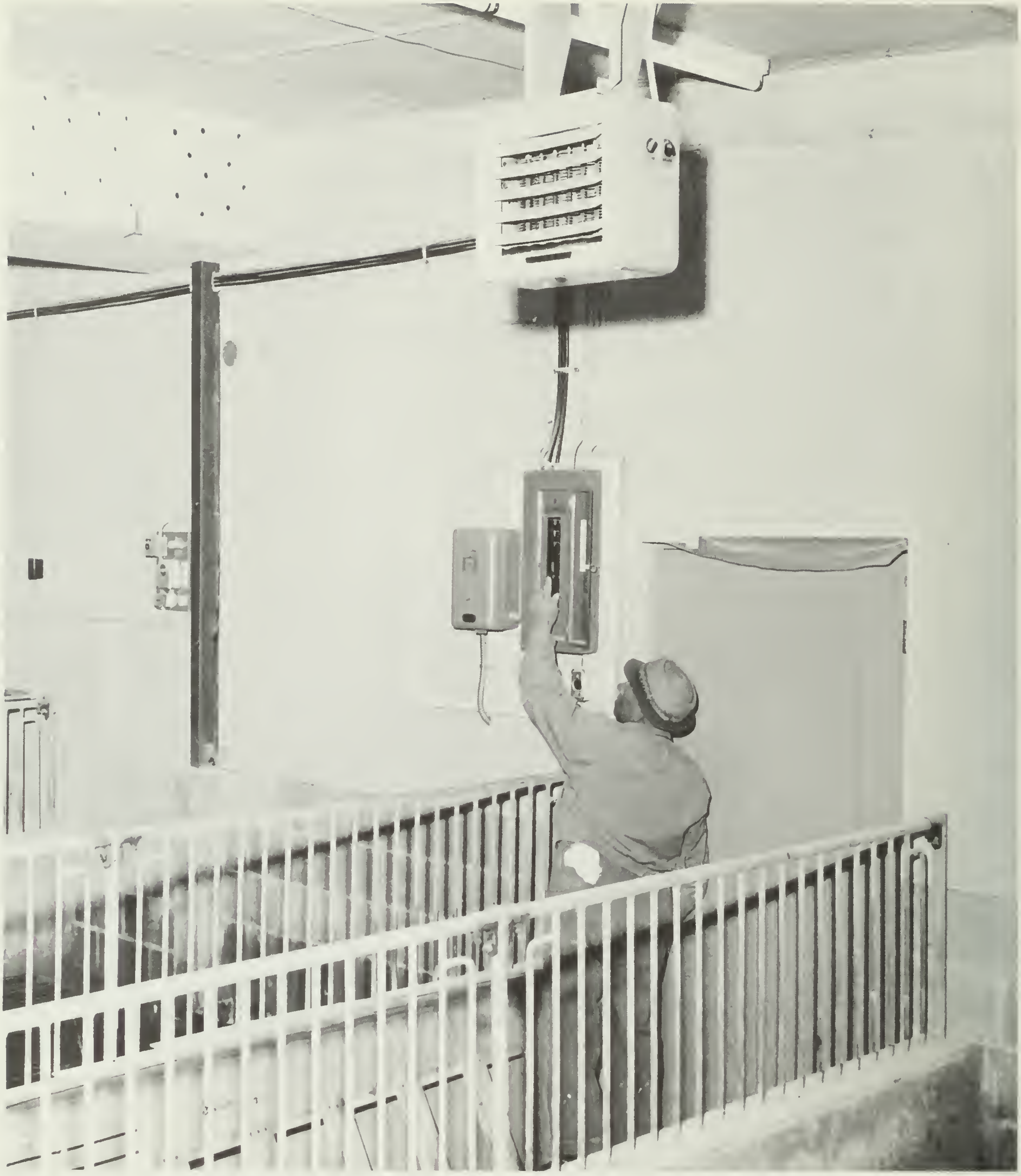


Figure 52. A fan-forced electric space heater in a weanling barn.

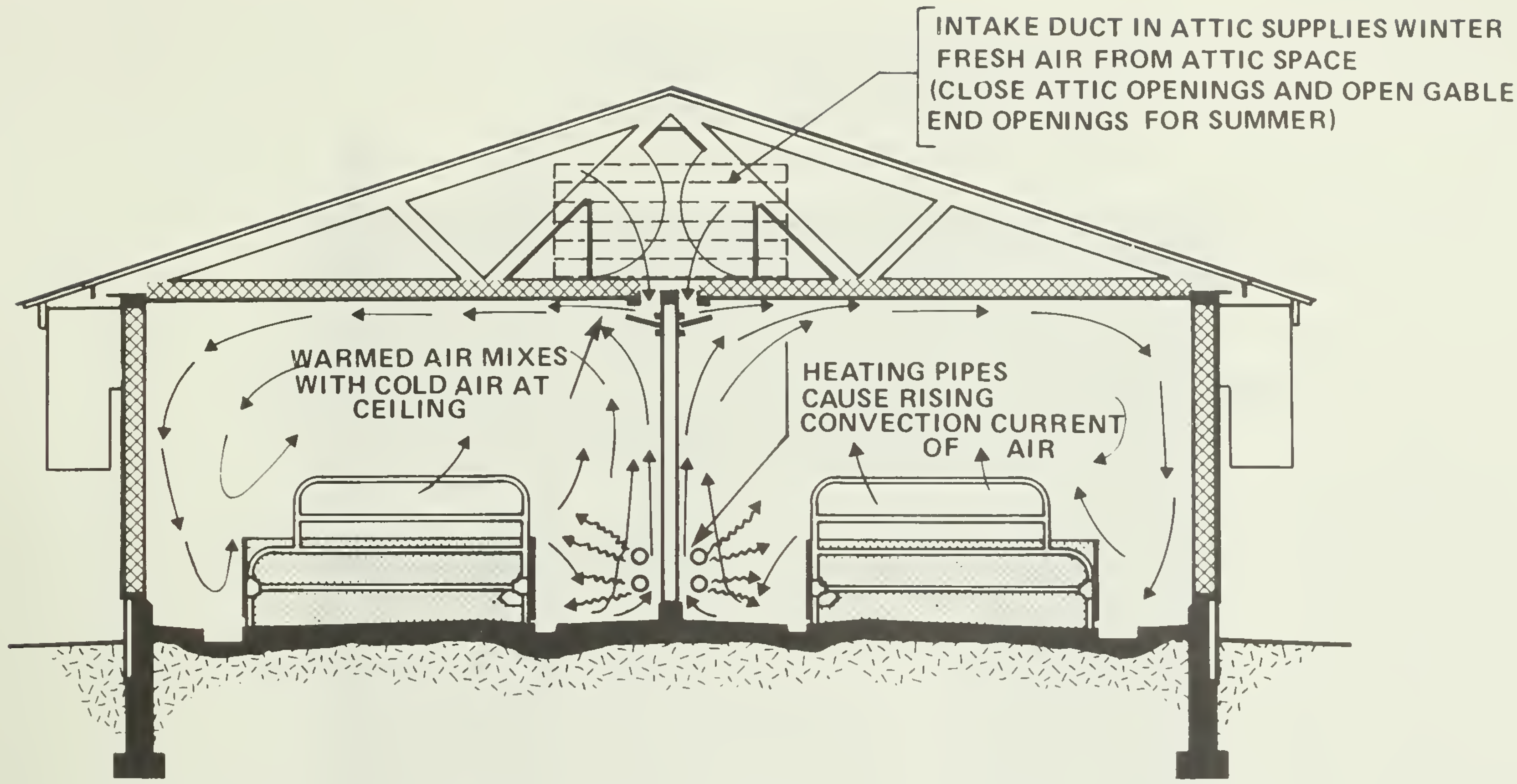


Figure 53. Black pipe hot-water radiators under the air inlet provide good distribution of fresh air for multiple-room farrowing.

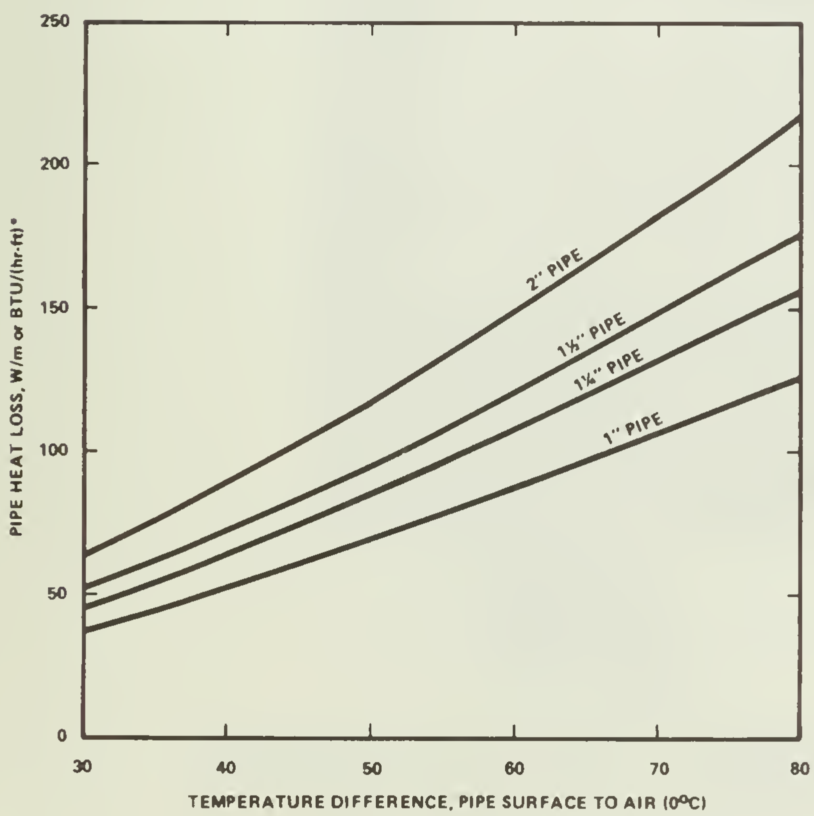


FIGURE 54. Heat output from horizontal black iron or steel pipe. *(Note: 1 BTU/(hr-ft) = 0.96 W/m, thus BTU equivalent is very close but not exact).

(Ref. 15). One manufacturer sells a convenient prewired control unit, including the thermostat, timer switch and fuse in a protective steel box, plus the remote solenoid valve (see Figure 56).

The hollow cone spray pattern is recommended since it provides the best opportunity for all pigs to get at the limited water supply. And locating the spray over the dunging area lets pigs 'take it or leave it'. Select a spray nozzle with a large droplet size and the smallest possible spray angle since the water sprinkled on the wall or the pen partitions will be wasted. Use stainless steel nozzle tips, but *not* hardened as these corrode quickly.

EMERGENCY WARNING SYSTEMS

With power-ventilated buildings, a failure of the ventilation or heating system for any reason can cause a disastrous loss unless the operator is warned in time. Emergencies include electric power failure, freeze-up of stopped ventilating fans, motor overload or burnout, and heating-system failure, to name only a few. The operator can handle most of these emergencies by connecting a tractor-powered standby generator or by opening outside doors and other emergency openings for natural ventilation. But he can only do this if he knows something is wrong.

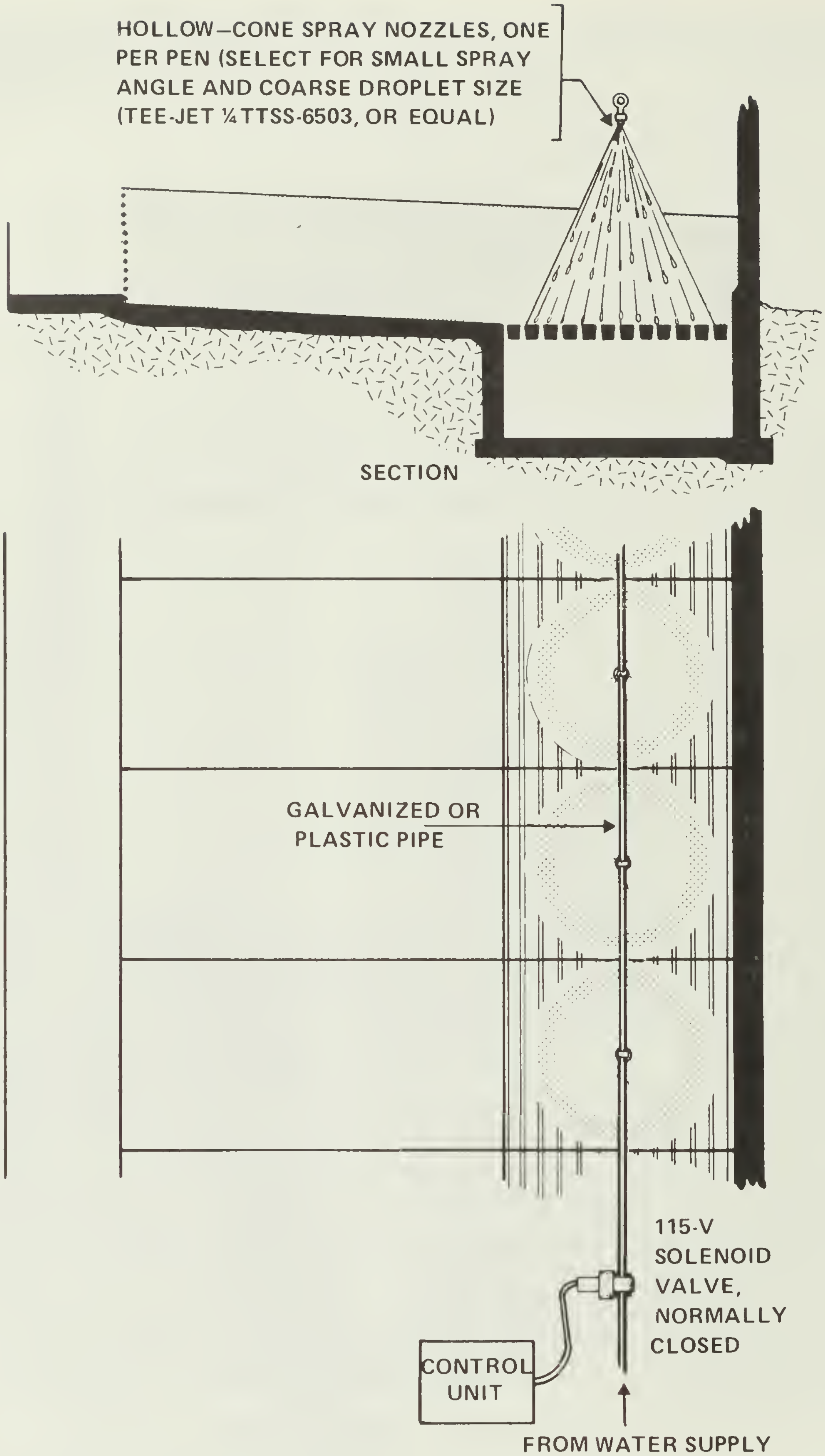


Figure 55. Sprinkler cooling system for finishing or gestation pens.

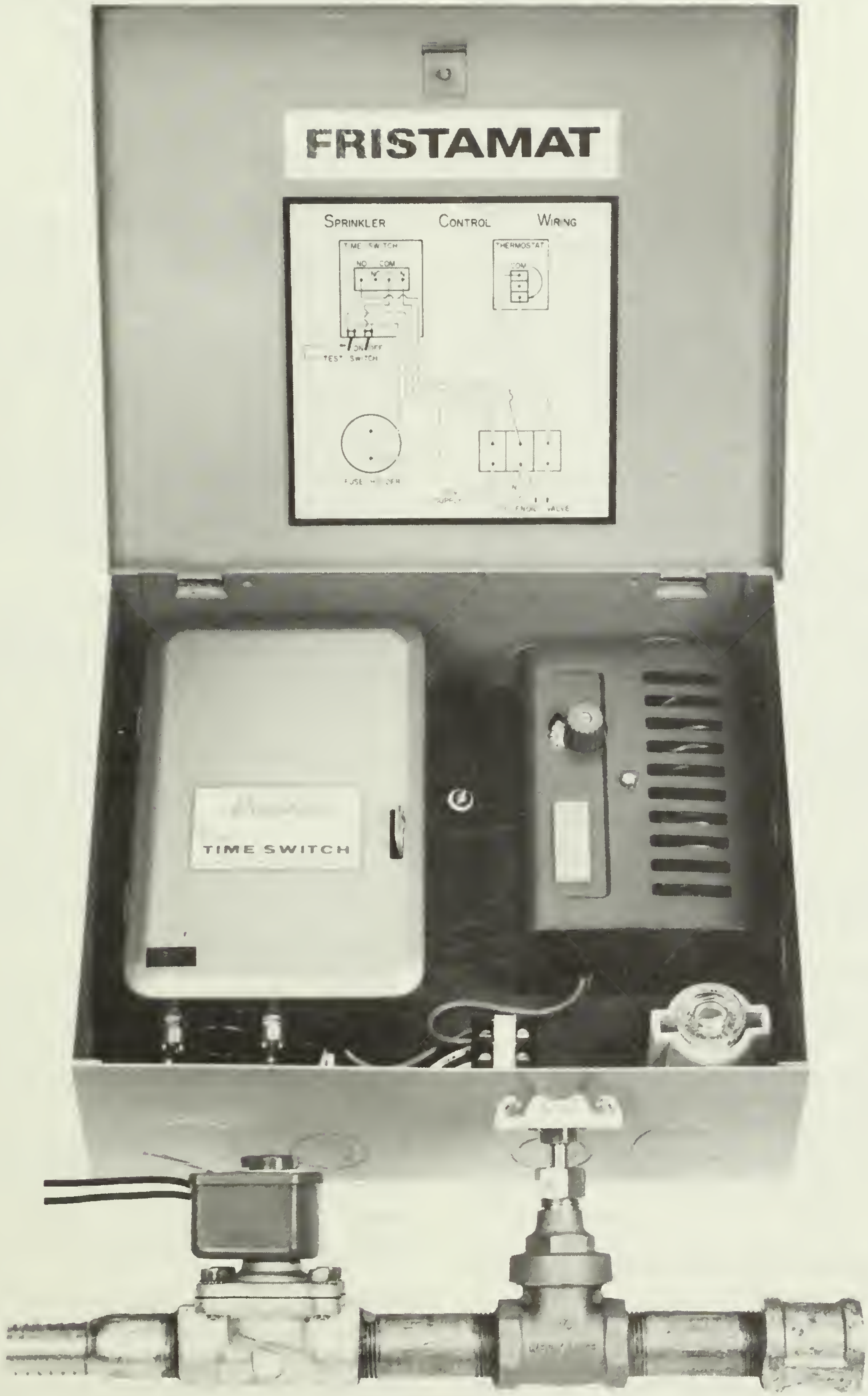


Figure 56. Prewired control system for sprinkler cooling. Photo courtesy of Faromor Industries, Ltd.

A power-off relay in the barn connected to a battery-operated buzzer or telephone in the house provides the simplest warning system, but protects only against general power failure in the barn. A better system uses a battery-operated warning circuit controlled by two-stage thermostats set to signal if barn temperature goes above or below selected temperature limits. Other warning devices such as furnace-room fire detectors may also be wired in series with the high-low thermostats if desired.

The insurance value and security provided by a good warning system can be worth many times the installation costs.

VIII. SWINE MANURE HANDLING

The waste handling system for swine housed in confinement must be carefully planned in order to meet all of the requirements of the management system. It must suit the arrangement of buildings, the layout of pens within buildings and the various types of pens or stalls to be used. Consideration must be given to the size of the operation, whether or not bedding is to be used, and whether or not groups of pigs are to be isolated from one another.

Swine manure is a valuable by-product of the swine production unit. With present technology, the most economical utilization of this by-product is to return it as a fertilizer to cropland, and preferrably the same land which grew the pig feed. As fertilizer costs continue to rise with increasing energy costs, this natural recycling system will become even more advantageous.

Manure safely stored for land spreading in the spring and fall fits best into a cropping program and minimizes risk of water pollution. On the other hand, spreading manure on snow, frozen soil or saturated ground is dangerous.

The method of handling swine waste divides into two areas depending on whether or not bedding is used.

SOLID MANURE HANDLING SYSTEM

The system for handling manure when bedding is to be used will be discussed only briefly. In the future, solid manure handling systems will be limited to some weanling pig production units and small farrow-to-finish units. Gutters can be equipped with chain or cable cleaners, provided that the saving in labor is sufficient to justify the equipment costs. The best layout has the gutter cleaner adjacent to pens where the biggest manure production occurs. These pens are scraped daily into the gutter under the pen partition or gutter guard (see Figure 57 A).

For multiple-room farrowing each farrowing room must be isolated, therefore a single gutter cleaner passing through all rooms is not acceptable. Since multiple farrowing rooms are generally small, often with no more than 12 pens, manual cleaning may be the only practical alternative. It may be possible, however, to arrange the farrowing areas so that short gutters can be scraped daily to a main gutter cleaner. In this case, the cleaner must be located in a passage outside of the farrowing rooms in order to avoid cross-contamination. To minimize alley space, the gutter should be just large enough to receive daily scrapings from the pen which it passes. If necessary, a small shovel or scraper can be specially made to fit a narrow gutter. The capacity of a gutter past one farrowing pen should be about 40 L. Additional information on the quantity of solid manure to be stored can be found in Table 11.

Manure from a 'solid' handling system may be stockpiled under the end of the gutter cleaner, but this poses several problems. Enough bedding must be used to make the pile manageable. A paved slab complete with a low concrete buckwall makes it easier to load the stacked manure into a spreader, However in many situations the concentrated runoff from the stack can drain into a nearby watercourse unless it is collected in underground holding tanks sized to hold the polluted runoff. This calls for a liquid manure spreader as well. The stack must be spread regularly in summer to control fly breeding, and the manure should be plowed in quickly for odor control.

LIQUID MANURE HANDLING SYSTEMS

Because of the difficulties involved in managing solid manure handling systems and because of the added labor and cost of the bedding, swine wastes are most commonly handled as liquid. In planning a liquid handling system, the most important aspects of the swine waste that must be considered are the flow characteristics, the volume to be handled and stored, and the gases and odors produced.

The flow characteristics depend on the type of feed, whether or not bedding is added, whether or not water is added, and the length of time it is stored. For example, the fibrous hulls of oats and barley contribute to the sludge that may build up in the bottom of manure pits and tanks. The waxy skin of coarsely ground corn may

TABLE 11. MANURE STORAGE VOLUME (REF. 12)

Class of swine	Manure production L/(pig • day)	* Required storage for liquid manure L/(pig • day)	Required storage for solid manure L/(pig • day)
18-91 kg (8 — 22 weeks)	5.1	7.1	7.1
4-11 kg (3 — 6 weeks)	1.1	1.6	
11-23 kg (6 — 9 weeks)	2.3	3.1	
23-34 kg (9 — 12 weeks)	3.4	4.8	
34-57 kg (16 — 20 weeks)	5.1	7.1	
57-80 kg (16 — 20 weeks)	7.4	10.2	
80-91 kg (20 — 22 weeks)	9.1	12.7	
Dry sow	11.3	15.9	13.6
Nursing sow and litter			
(wean at 3 weeks)	15.6 (Ref. 12)	21.8	
(wean at 6 weeks)	19.5 (estimated)	27.5	

* This column is calculated from 'Manure production' by a multiplying factor of 1.4 to allow for water spillage from waterers, floor washing, and dilution water where required.

also appear as sludge in tanks. Fine grinding of feed does not reduce the amount of undigested sludge, but fine hulls settle more slowly and are less likely to accumulate in temporary storage pits and gutters.

See Table 11 for the volume of manure produced by pigs at various stages. These quantities can be used to estimate the sizes of gutters and storage tanks required, as follows:

Example – check gutter size behind a row of gestation sow stalls; Gutter selected is

$$\frac{300 \times 75 \times 600 \text{ mm (stall width)}}{1\,000\,000 \text{ mm}^3/\text{L}} = 13.5 \text{ L}$$

This is just adequate to hold 11.3 L of manure from a dry sow (Table 11, column 2).

Example – calculate total manure storage for 8 months from a 500 – hog grower – finisher unit;

$$\frac{500 \text{ hogs} \times 8 \text{ mo.} \times 30 \text{ days} \times 7.1 \text{ L}}{1\,000 \text{ L/m}^3} = 852 \text{ m}^3$$

CONTROL OF GASES AND ODORS FROM STORED SWINE MANURE

Fresh swine manure inevitably produces a mixture of odors which are unpleasant to humans but not particularly dangerous. However, untreated manure accumulating for some time in gutters and storage tanks becomes a culture for bacteria which multiply and feed on the manure. In the typical environment of a pig barn, bacterial action quickly uses up any oxygen in the manure, therefore only *anaerobic* bacteria can survive and multiply. These bacteria produce a number of foul and dangerous gases, including ammonia, hydrogen sulphide and a large group of trace organic compounds.

These gases are extremely dangerous to humans and livestock. For example, hydrogen sulphide in the barn atmosphere is dangerous to humans at only 1/5000 concentration, and is deadly at 1/1000. One would suspect that pigs living constantly in the barn would be adversely affected at much lower levels of concentration. Gases are particularly dangerous because they can accumulate in the storage as tiny bubbles attached to manure particles. When the manure is agitated in order to empty the tank, the bubbles are released suddenly, resulting in gas concentrations in the air many times higher than 'normal'. For example, a full storage under a partially slotted floor is agitated; the pigs are attracted by the noise, and they nose around the slotted floor just in time to receive a deadly dose of the poisonous gases.

Since hydrogen sulphide is slightly heavier than air (specific gravity 1.2, or 20% heavier), there may be some benefit in continuously exhausting some of the ventilation air from just above the surface of the stored manure, below the slotted floor. The problem here is that there is no sure way to force ventilation air to move downwards though the slotted floor throughout the barn, and pens farthest from the exhaust fan will have no protection.

Management practices can minimize the dangers of manure gas poisoning. Since the gas hazard increases with storage time, swine barns can be planned and operated so that the manure is removed frequently to separate storage. This applies not only to buildings with solid floors, but also to slotted floor systems. Where manure is stored for some time under slotted floors, it is

safer to remove it without prior agitation. During removal, open all outside doors for maximum wind ventilation to supplement the fans. If doors are left closed, exhaust fans can draw air through the pump openings by way of the manure trenches instead of the ventilation inlets.

Provide a gas trap wherever an animal area connects to a storage tank. This trap can take several forms.

One solution to the manure gas problem is *aeration* to feed oxygen continuously into the manure; this allows growth of aerobic bacteria which tend to produce relatively harmless by-products such as carbon dioxide and water instead of poisonous gases. Aeration is done by mechanically beating air into a trench used for circulating the manure (the 'oxidation ditch') or by bubbling or blowing air bubbles into the storage tank. These systems when properly designed will control odors in the barn, but there are problems with high energy consumption, mechanical breakdowns and excessive foaming.

Some operators are now using mechanical aeration in a small part of the manure storage to produce an odor-free liquid suitable for pumping back into the barn for flushing the gutters. This way manure is rapidly removed from the barn without adding huge volumes of fresh flushwater, all of which must be ultimately carried to the field for disposal.

Another treatment system is the *anaerobic digester*, a gas-tight tank which is insulated and heated to 32 to 37°C. The tank is seeded with heat-tolerant bacteria which multiply and attack liquid manure, producing carbon dioxide, water and methane (a combustible fuel gas). Part of the methane can be used to maintain digester temperature, and any left over can be used for other purposes such as heating the barn. The treated manure is reduced to a dark-gray liquid, relatively odor-free, but still retaining most of the fertilizer value of the original manure. Many experts feel this system has much future potential, but there are problems such as high initial cost, explosion hazards, and storage of the methane for later use (methane is a gas which, unlike propane, does not liquify when stored in a pressure tank). With present technology, the anaerobic digester in cold weather barely produces enough gas to maintain its own operating temperature.

MANURE REMOVAL FROM BARN TO STORAGE

The manure removal system begins in the pen, with the proper floor slopes, pen shapes and the use of slotted floor area. Figure 57 illustrates typical growing-finishing floors and gutters. These pens work best if they are long and narrow, from a minimum of 1.5 × 4.8 m and up to 2.4 × 6 m. With solid floors, a 100 mm step about 1.2

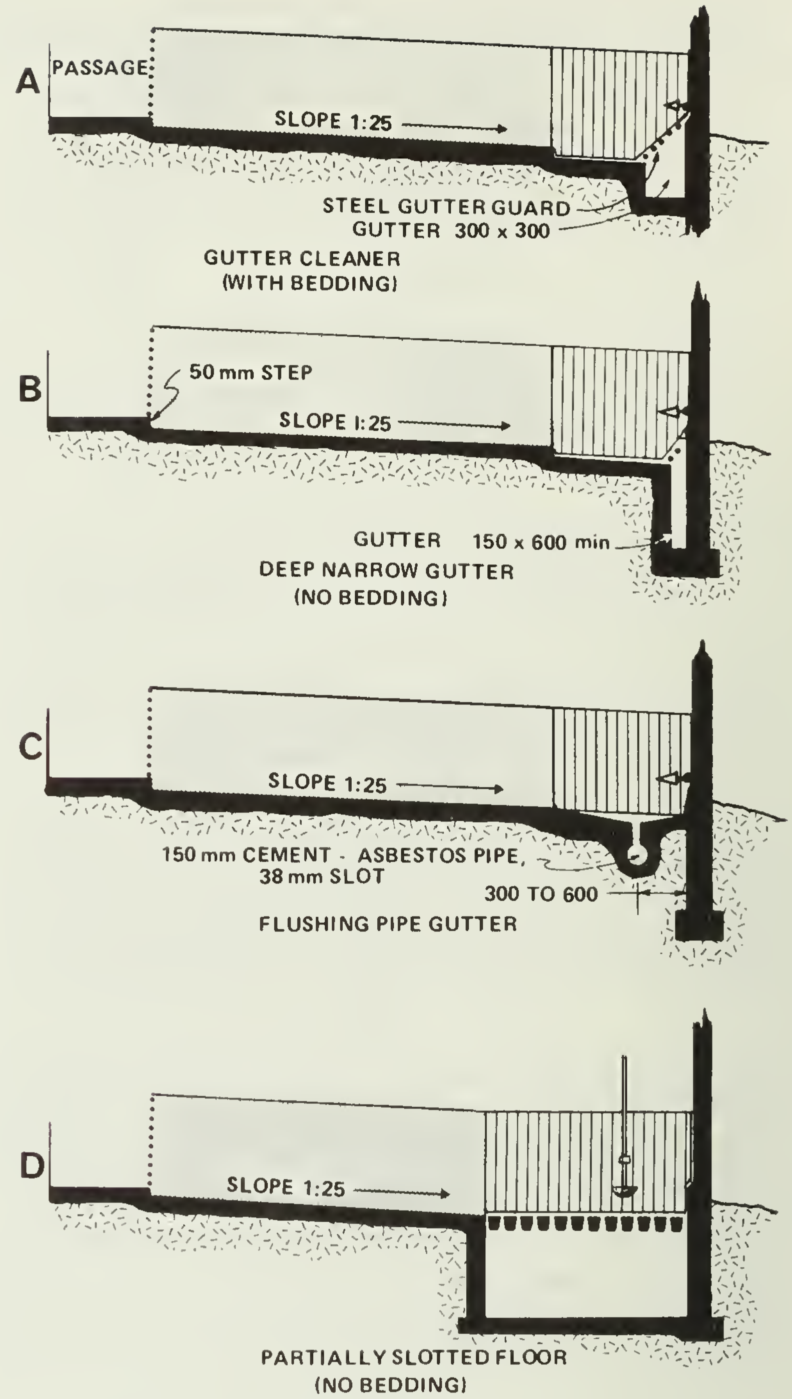


Figure 57. Growing-finishing pens with four manure removal systems.

m from the outside wall helps separate wet from dry floor areas. Some operators prefer not to use the floor step, but to use a steeper floor slope at the dunging area.

With slotted floors, from 30% to 100% of the pen floor may be slotted; for pens 4.8 m long, a slotted floor 1.8 m long is recommended. In various experiments to determine the optimum floor arrangement, growing-finishing pigs on part-slotted and total solid floors have consistently gained faster and with less feed than those housed on 100% slotted floors. It is difficult to know exact reasons for this, but drafts and manure gases rising from the tank space below may be part of the problem. Another problem with 100% slotted floors is that any feed spilled from the self-feeder is forever lost into the tanks below. Unlike solid floors, this loss is not

always obvious to the operator and needed adjustments may not be made to the self-feeder.

Solid floor slopes are normally 1:25 towards the gutter or slotted area. If the slope is longer than 3.6 m, a flatter area sloped at 1:50 can be provided near the pen front. This reduces the total floor drop. For sow gestation stalls, too much floor slope can cause prolapse; a floor slope of 1:100 is recommended for the lying area, with a steeper slope at the rear (see Figure 8, page 16).

Concrete is the preferred material for floors, both solid and slotted types. The only possible exceptions to this are perforated floors in farrowing crates and weanling pens. Concrete pen floors should be made from the strongest mix available, finished smooth enough to prevent abrasions to feet and legs, but not polished so smooth that they become slippery.

Solid-floor growing pens usually are scraped daily with a steel scraper or rubber squeegee. This operation can transfer infection from pen to pen. Some operators prefer to accept a buildup of manure on the floor rather than risk the spread of infection, but they must tolerate increased manure odor and water vapor added to the air, and the resulting stress on the pigs.

The gutter may be inside the pen with a raised guard. However, since the space occupied by the gutter is not usable by the pigs, it is often more practical to partition the gutter out of the pen.

Partly slotted floors usually require no scraping, therefore both the labor required and the risk of spreading infection are eliminated. In addition, the floor stays drier and less moisture is added to the room air. Partly slotted floors are also useful for dry sow stalls, resulting in cleaner sows, a dry floor and a minimum of scraping. Since the cleaning of floors is complicated by the stall partitions and gates, the additional cost of a slotted floor can be justified.

Partly slotted floors are used more and more in farrowing pens. Partly slotted floors keep farrowing pen floors drier, and reduce labor in pen cleaning. Disadvantages however are higher cost, and added stress on baby pigs due to convection drafts, manure odors and uncomfortable footing. If the slots are wide enough to pass sow manure (see Table 12), they must be covered for the first 2 days after farrowing. With concrete slotted floors, some operators make a removable grill of steel rods spaced to fit into the floor slots. The rods are welded to flat steel spacer strapping which rests across the top of the slats. The grill is removed as soon as the baby pigs are agile enough to safety walk over the slotted floor areas.

Slats are made from a variety of materials. Local hardwood is the least expensive, and is quite satisfactory for weanling pens. For larger pigs, hardwood slats wear out too rapidly. Treated wood is not recommended. Steel is relatively expensive and rusts rapidly unless it is hot-dip galvanized or epoxy-coated. Galvanized expanded steel mesh (made by slotting and stretching heavy steel sheet and rolling it flat) has been used successfully for weanling pen floors, but for farrowing pens it has caused injuries to the sows' teats. Sheet steel folded into channels and punched with oblong holes is more satisfactory for farrowing pens. Aluminum alloy and plastic slat grids are also available, but quite expensive.

Reinforced concrete continues to be the most popular material for slotted floors; it is very durable if made carefully from high-strength concrete, and less expensive than all other materials except wood. In growing finishing pens, slats may be placed parallel to the manure trench (as in Figure 57D) or across the trench; there are advantages to both methods. Slats placed parallel to the trench (Figure 57D) with a special slot about 50 mm wide at the outside wall help eliminate manure buildup at the wall and at the line where sloped floor meets slotted floor. On the other hand some authorities indicate pigs walk more confidently on slats fitted across the trench, and especially if the slats are wide (200 mm has proven satisfactory).

For recommended slat widths and spacings, see Table 12.

TABLE 12. RECOMMENDED SLOT OPENINGS WITH NARROW AND WIDE SLATS (REF. 5)

	Narrow slat (30 to 50 mm)	Wide slat (100 to 200 mm)
Newborn pig.	9 mm	9 mm or *25 mm
11 to 18 kg pig	13 mm	20 to 25 mm
18 to 100 kg pig	not recommended	25 mm
Sow	not recommended	30 mm

* When 25 mm spacing is used with newborn pigs, cover with grate first 2 days. Slot openings from 13 to 20 mm can trap baby pigs' feet.

LIQUID MANURE GUTTERS

Many different systems are being used for removing liquid swine manure from gutters, at and below the floor level; some of the most popular are as follows:

1. Shallow scraped gutter.
2. Deep narrow gutter.
3. Flushing pipe gutter.
4. Channel under slotted floor;
   (a) draw-off pipes for vacuum tanker
   (b) pail valve gravity outlet
   (c) continuous flow, or 'lip' system
   (d) flushing channel systems

The shallow scraped gutter is the most practical behind short rows of stalls or farrowing pens. Since it usually robs some passage space, it should be no more than 200-250 mm wide. Drainage gutters at the front of farrowing crates may be even narrower (150 mm is typical). It is usually worthwhile to have a special shovel or pusher made to fit the gutter. A variation of this gutter type is used with the cantilever farrowing pen (see Figures 12 and 13, pages 19 and 20). The gutter is cleaned by pushing the manure to a sump or deeper gutter at the end.

The deep narrow gutter (Figure 57B) is effective for collecting and removing liquid manure from all types of pens except dry sows. For farrowing pens it may be necessary to add extra water for flushing. The deep narrow gutter is self-draining because with small capacity it fills quickly, allowing little time for heavy feed particles to settle out. The 150 mm width is preferred as long as it will hold 2 days accumulation of manure. The walls and floors should be tied together with reinforcing steel to insure against cracks that would drain away the liquid. The gutter must be fitted with a watertight plug or gate that can be opened as often as once each day to drain the contents into the storage tank. An effective plug, shown in Figure 60, is constructed from two plastic pails.

The *flushing pipe gutter* (see Figure 57C) can be used instead of the deep narrow gutter, in situations where construction of the deep gutter poses problems (remodelling old barns, for example). The flushing pipe gutter is usually made by inserting a 150 mm asbestos-cement flushing pipe into the floor, near the back of the pen.

Slope the flushing pipe uniformly at 1:250 towards a small concrete collecting sump of about one cubic metre capacity at the outlet end. A smooth 38 × 140 board is laid on edge to form a continuous drainage slot when the concrete floor is placed. After the concrete hardens, remove the board and saw the pipe to open the slot. The 1:250 pipe slope can be accommodated by tapering the depth of the board, or by sloping the pen floors at 1:250 towards the outlet.

Flush the pipe gutter once or twice per day with an electric submersible sewage pump (2-inch pipe size, or more) connected by overhead piping to discharge at the top end of the gutter. It is most convenient to install the sewage pump directly into the collecting sump, and connect gate valves and piping to allow either recirculation of liquid manure back to gutter or pump out to long-term storage outside.

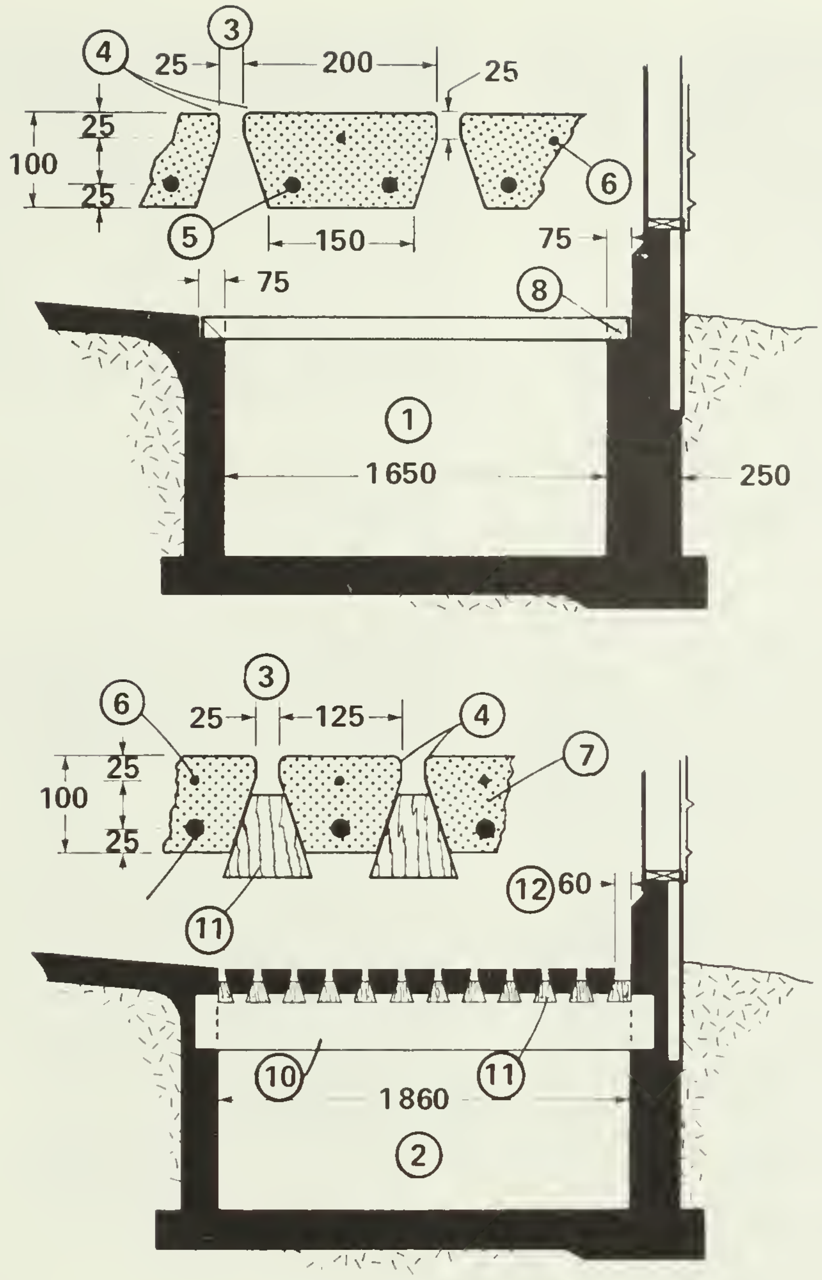
This is an extremely flexible system; the same collecting sump and sewage pump can be connected to flush several barn areas, and fill one or more storages. Storages may even be situated higher than the gutters if site requirements so dictate. Be sure to connect the sewage pump to the piping with unions or other quick-couplings so that the pump can be lifted out easily in case it plugs.

Channels under slotted floors (Figure 57D) may be 300 to 1 800 mm deep; this can provide temporary storage from one day to 15 weeks depending on the area of slotted floor per pig and the depth of stored manure at cleaning (usually 300 mm less than the total depth). Shallow channels cleaned frequently can minimize manure gas problems in the barn.

Where climate and type of farming permit spreading manure at frequent intervals, the deeper channels may provide enough storage. In this case, use pipe cleanouts for unloading by vacuum tanker (see Figure 59). Manure should not be expected to flow more than 4 m to a cleanout. For complete cleanout the sump under each cleanout pipe should be at least as deep as the diameter of the cleanout pipe and tanker suction hose. The submerged cleanout pipe also provides a gas trap, since a small amount of water in the sump prevents the exhaust ventilation fans from drawing air through the manure channels.

Where more storage is required than that under the slotted floor (the more typical situation), channels and collecting sumps may be emptied frequently and quickly as shown in Figure 60. With this *stop-and-flow gravity system*, one of the critical problems has been to make the outlet valve completely watertight, otherwise the liquid fractions drain off. This leaves the settled solids concentrated and difficult to remove. Figure 60 (insert) shows one solution to the leaky valve problem; a valve made from 2 matched plastic pails has become popular due to its simplicity, reliability and low cost. The lifting hook-handle may be separate as shown, or it may be a permanent attachment.

The stop-and-flow system shown in Figure 60 is an extremely flexible arrangement; the branch sewer pipes



1. WIDE CONCRETE SLATS LAID ACROSS MANURE CHANNEL
2. NARROW CONCRETE SLATS LAID PARALLEL TO MANURE CHANNEL
3. SEE TABLE 12 FOR SLOT WIDTHS SUITED TO OTHER SIZES OF PIGS
4. SMOOTH 'PENCIL' RADIUS PREVENTS CHIPPED EDGES
5. BOTTOM REBARS, 2 OF 10M SIZE FOR 1800mm SPAN AS SHOWN
6. TOP REBAR PREVENTS BREAKAGE WHEN LIFTING SLATS
7. CONCRETE, 35MPa STRENGTH, MAX. AGGREGATE 12mm
8. ENDS OF SLATS GROUTED IN WITH MORTAR TO HOLD UNIFORM SPACING
9. BOTTOM REBAR SIZE 15M FOR UP TO 1500mm SUPPORT SPACING
10. 38X235 PRESSURE TREATED WOOD SLAT SUPPORTS BEDDED IN MORTAR INTO POCKET 75mm DEEP FORMED WITH POLYSTYRENE BLOCK; SUPPORT SPACED 150mm FROM EACH END OF SLATS UP TO 1800mm LONG
11. SPACER WEDGES OF 12mm EXTERIOR PLYWOOD, SOAKED IN WOOD PRESERVATIVE, GALVANIZED ROOFING NAILS INTO SUPPORT BEAMS (10)
12. WIDER SLOT AT WALL PREVENTS MANURE BUILDUP, REDUCE TO 38mm FOR WEANER PIGS

Figure 58. Concrete slotted floor details for swine pens. With this support method, slats can be laid parallel to the walls for better self-cleaning.

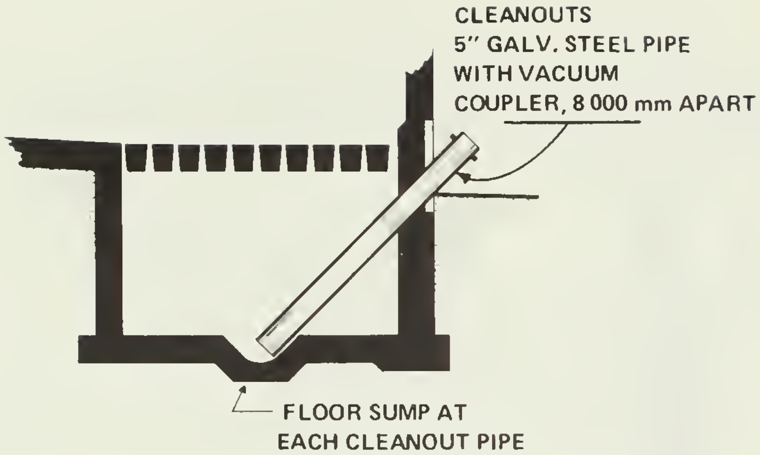


Figure 59. Slotted floor trench equipped for vacuum tanker cleanout.

are buried below frost outside and below manure trenches inside. To keep gutters short inside the pig barns, the branch sewers should in general cross approximately under the mid-length of each animal area (see Figures 16 through 22). Animal areas with free-flowing manure (grower/finisher, weaner units) should be connected near the upper end of branch sewers, and problem areas (gestation, farrowing barn) should be connected closer to the outlet end. All branch sewers should be gas-trapped at the collector pit as shown at 10, Figure 60.

Exhausting one small continuous-running fan from the last building into the top of the collector pit prevents winter freezing in the main sewer (11) running to the long-term storage. With this feature, the main sewer is not necessarily laid below frost depth, but it should be larger (300 mm suggested) to ensure that flow of warm exhaust air is not restricted. Or if the main sewer pipe (11) is too long and expensive at 300 mm size, make an adjustable air outlet from the insulated duct above the pit, and reduce sewer (11) to 200 mm.

In summer, the air-duct from fan to collector pit should be removed, otherwise the flow of warm summer air can dry out the main sewer and cause plugging.

In some situations, small exhaust fan (2) can be relocated and connected by duct to draw air from under the slotted floor at area (5); this provides some measure of manure gas control above the pit.

Another variation on the gravity system is to use the *continuous flow* (or *lip system*, as it is frequently called in Canada). The continuous flow (lip) system has been used for several decades in Europe; it has the advantage that it functions well with much less dilution washwater than other liquid systems such as the stop-and-flow.

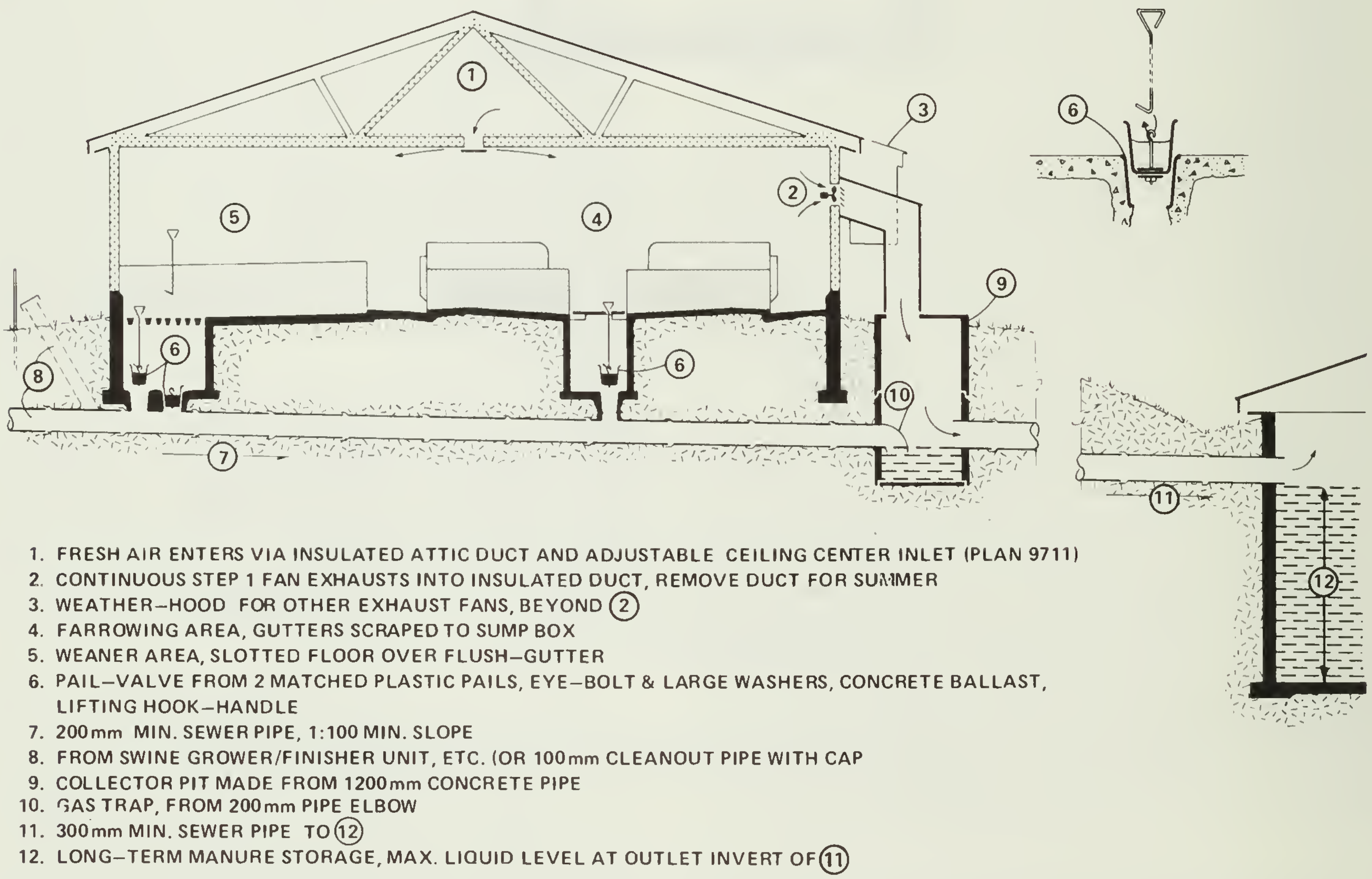
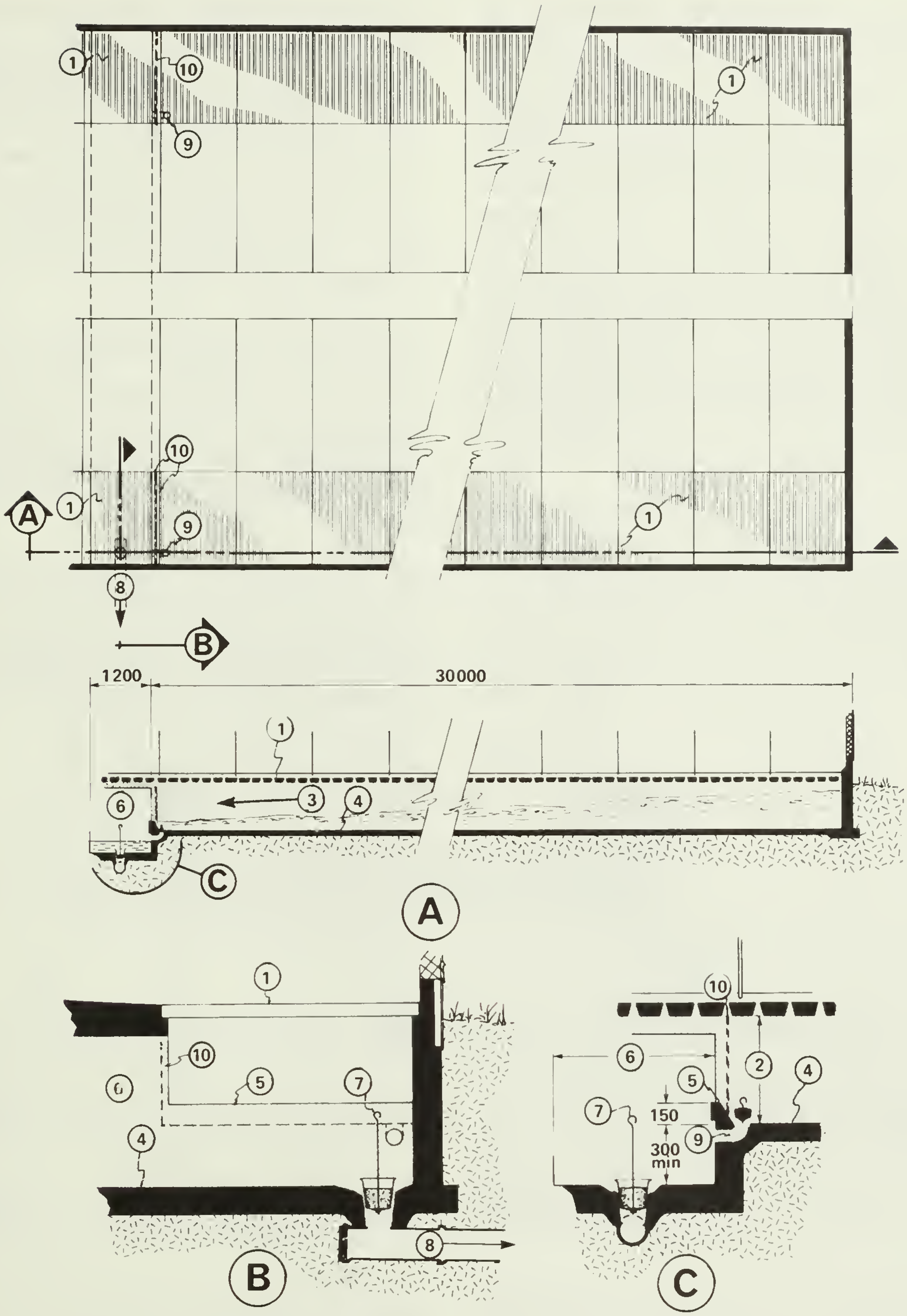


Figure 60. Typical liquid-manure storage system with gravity flow to remote long-term storage, and exhaust ventilation frost protection.



1 slotted floor over manure channel
2 depth depends on channel length—see table 13
3 liquid manure surface, slopes 1:00 to 1:30
4 channel bottom water tight, smooth and level
5 overflow dam, top edge level
6 cross—channel accumulates manure 2–3 days
7 pail-valve; see inset, figure 60
8 200 mm sewer pipe to long term storage, min slope 1:100
9 channel drain from 100 mm plastic pipe elbow, rubber plug & eye-hook
10 25mm grooves in sides of channel, 19mm plywood sluice gate optional

Figure 61. Continuous flow manure system, adapted to a slotted-floor growing/finishing barn (like CPS plan 3428).

Figure 61 shows some typical details. Each manure channel bottom is made *smooth, level* and *manure-tight.* Across the outlet end of each channel, a small full-width weir with top edge *exactly level* and about 150 mm high traps liquid manure so that the channels never dry out and 'stick'. The manure soon starts to trickle over the dam, and the manure surface in the channel then builds up to a slope, which depends on solids content; typical slope is from 1:100 to 1:30. Manure accumulates deepest at the end remote from the overflow; the longer the channel, the deeper it must be to provide depth for the manure slope without over-filling the channel at the top. Table 13 based on German literature, gives channel lengths and corresponding channel depths recommended for feeder pigs. The lip system is not recommend for dry sows.

TABLE 13 CONTINUOUS FLOW (LIP SYSTEM) CHANNEL LENGTH AND DEPTH REQUIREMENTS FOR FEEDER PIGS

Channel length (m)	Channel depth (mm)
15	700
20	800
25	800
30	900
35	1 000
40	1 000

Channel width is not too critical; widths from 1.0 to 2.4 m are common. With wider channels, there is more tendency for the liquid fractions to separate into meandering flow. Channels over 30 m long sometimes give trouble; for long barns it is better to step down to an outlet cross-channel at mid-length. The outlet cross-channel should step down at least 300 mm deeper than the long channels, and it must have a gas trap where it flows into long-term storage.

A small drain elbow and stopper in the channel bottoms just above each step allows periodic drainage of the channels, such as when a barn is depopulated and sanitized to control disease. Some owners have also added a set of vertical grooves in the sides of the channels just upstream of each step; with this, a plywood sluice-gate can be dropped into place across the channel, to stop flow temporarily for flushing the channel above, or for servicing sewer connections below the step.

The *flushing channel systems* now in use are too numerous to be described here in detail. In principle these systems use a small liquid-manure pump to recirculate either fresh or mechanically-aerated liquid waste back to the remote end of each manure collecting channel. Here a series of flushing tanks or self-dumping tanks accumulate flushing water until full, then suddenly discharge into each channel. A wave of liquid rushes down the channel carrying manure and urine into the sump. One variation is to use a larger manure pump and eliminate the dump tanks, and another is to flush a wide shallow gutter running at floor level through a row of pens.

THE LIQUID MANURE STORAGE SYSTEM

Except where adequate storage can be provided in pits under slotted floors, the swine production unit must be provided with a manure storage that can receive and store manure between the times that it can be agitated, loaded and spread on cropland.

(1) BELOW-GROUND STORAGE SYSTEM

The most common storage system uses a below-ground storage tank and gravity flow from the gutters to storage. Figure 60 illustrates this principle; one or several deep gutters connect to a collecting sump just outside the barn wall. From this sump, a sewer pipe drains to a below-ground storage some distance from the barn. Slope the sewer at least 1:100, and make very sure it empties above the maximum storage level of the 6-months storage tank; if liquid manure backs up into the sewer, sedimentation and plugging will occur.

Make the sump from sections of concrete culvert pipe of at least 1 m diameter, and pour a concrete floor to seal the bottom. To make a simple gas trap, locate the invert (bottom inside) of the outlet sewer a little above the pipe outlet elbow 10 coming from the barn.

If the building elevation is too low or the distance is too far to permit gravity flow from gutters to storage, then it is quite feasible to pump the manure to below-ground storage. Using a pump, the storage elevation can then be chosen for the most economical storage and piping design. With conventional tractor-powered equipment to agitate and pump from storage, the storage should be mostly below ground.

Below-ground storages include the earth storage pond, and rectangular or circular concrete tanks. The earth storage pond can be cheaper than other types but it is limited to heavy clay subsoil, otherwise an impervious lining must be provided. Other requirements include a dyke to exclude surface runoff water, a good fence to exclude children and livestock, and a pumping dock if a tractor-pto pump is to be used. Concrete tank construction is described later.

(2) ABOVE-GROUND STORAGE SYSTEM

Above-ground circular tanks have a number of advantages over below-ground tanks:

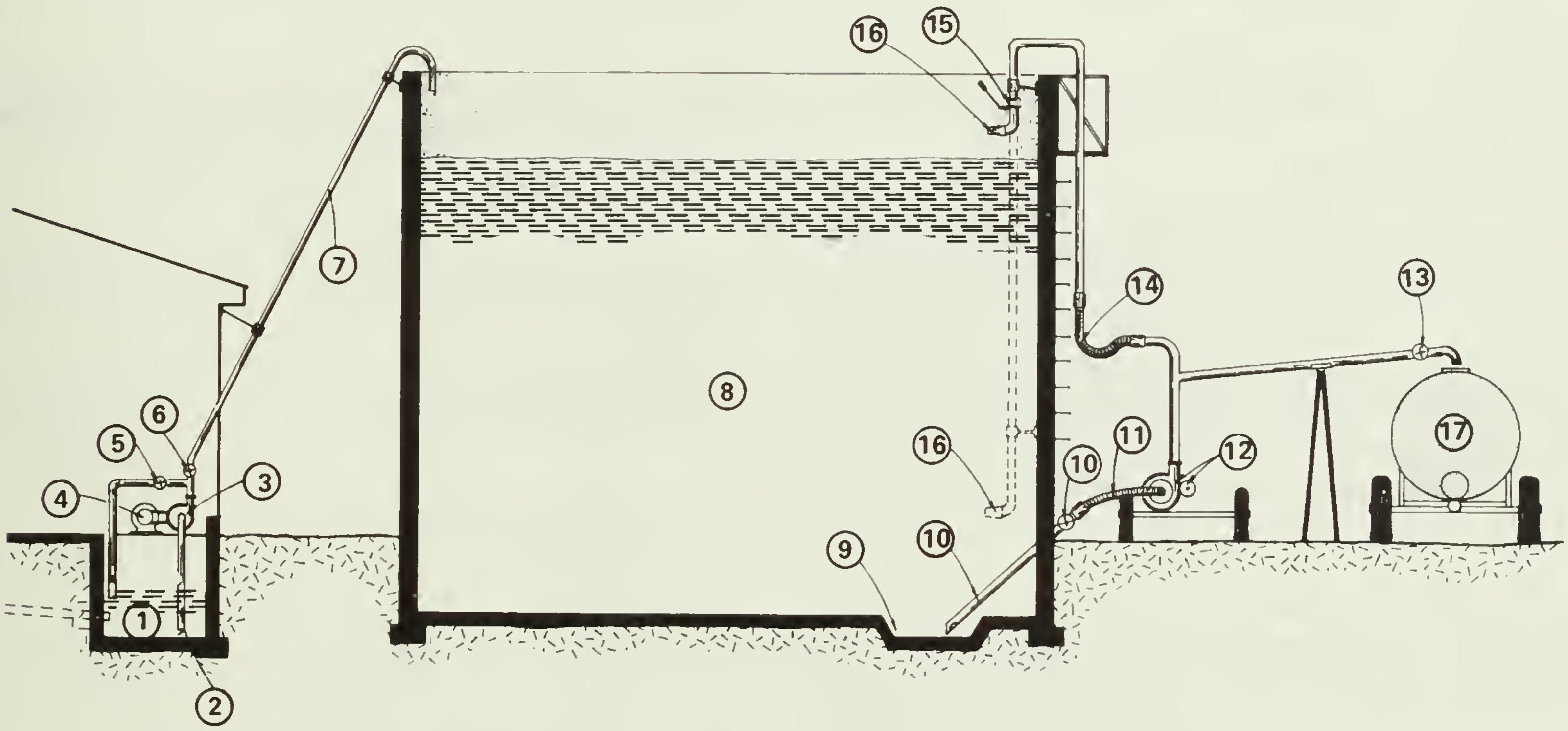
1. They can be constructed where a high water table prohibits below-ground storage.
2. They do not require a fence or roof.
3. Excavating costs are minimized.
4. The contractor is encouraged to cast high quality concrete, since the leaks will be clearly visible.
5. Working conditions for constructing the walls are better above ground than below.
6. For the available tank diameter, an above-ground tank can have much greater capacity than a below-ground tank because it is not limited to 3 or 4 m in height.

Many pumping arrangements have been tried for filling and emptying above-ground manure storages; four arrangements are described in Ref. 16 and one of these is illustrated in Figure 62. Here a relatively small electrically-driven pump in the barn is used to transfer liquid manure to long-term storage. A piping arrangement in the barn permits this pump to stir the liquid manure in the holding sump, before transfer to storage outdoors.

The filling pipe goes over the top of the storage wall to eliminate the possibility of accidentally flooding the barn. This pipe must be drained to prevent freezing in winter.

Another possibility for manure transfer is to use an electric submersible sludge pump, 2 1/2 – or 3-inch size. With a submersible pump installed below the liquid level in the sump, the troublesome foot valve and suction pipe are eliminated. Be sure that the plumbing allows for easy lifting of the submersible pump, in case of plugging.

When the above-ground storage is almost full, a separate tractor-driven pump is connected, to agitate the manure and load the tanker. Tractor PTO-driven centrifugal irrigation pumps will develop the pressure and flow required for agitation but there may be some trouble with solids plugging the closed-type pump impellers.



1. CONCRETE SUMP, 2 TO 7 DAYS LIQUID MANURE STORAGE
2. MANUAL FLAP-TYPE FOOT VALVE (NOT REQUIRED IF PUMP IS SELF PRIMING), SHORT STRAIGHT 3" SUCTION PIPE TO PUMP
3. 3" OPEN-IMPELLER CENTRIFUGAL PUMP
4. ELECTRIC MOTOR DRIVE, 1.5 TO 3.5 kW DEPENDING ON PUMP CHARACTERISTICS
5. 2" OR 3" GATE VALVE AND RETURN LINE STIRS MANURE IN SUMP 1 OR DRAINS FILLER PIPE 7
6. GATE VALVE CLOSED FOR RECIRCULATION, OPEN FOR FILLING
7. 2" OR 3" FILLER PIPE TO STORAGE
8. REINFORCED CONCRETE SILO, 7.2 OR 9.0m DIA., UP TO 9m HIGH
9. SUMP IN FLOOR 300mm DEEP AT SUCTION PIPE INTAKE
10. GALV. STEEL SUCTION PIPE AND GATE VALVE TO MATCH PUMP 12
11. FLEXIBLE SUCTION PIPE WITH QUICK-COUPLERS BOTH ENDS
12. TRACTOR PTO-POWERED CENTRIFUGAL PUMP
13. OVERHEAD FILLER PIPE AND GATE VALVE, TO TANKER 17
14. FLEXIBLE PRESSURE PIPE, QUICK-COUPLER BOTH ENDS
15. PIPE SWIVEL CONNECTION WITH HANDLE TO DIRECT NOZZLE 16
16. AGITATOR NOZZLE, ALTERNATE LOCATIONS
17. LIQUID MANURE TANKER TO FIELD

Figure 62. Above-ground liquid manure storage silo, two-pump system.

The suction pipe and valve (10) must be securely fixed to the reinforcing steel in the silo wall, to maintain a watertight connection. The suction pipe and valve are installed at 45° slope to minimize elbows and fittings which can restrict flow and cause plugging problems. The exposed parts of this suction pipe and valve can freeze, but this is not a problem as long as the storage is big enough to eliminate the need to pump and spread manure in the winter period.

TANK CONSTRUCTION

Rectangular concrete tanks are constructed 2.4 to 3.6 m deep, usually with cast-in-place concrete floors, walls and top. In areas where there is a large market for manure tanks, precast rectangular tanks may be available. A top designed to support vehicle traffic is a luxury and can cost as much as 40% of the total cost of the tank. Therefore, the tank should be constructed with the walls extended above grade to stop tractors and trucks from driving over. This way the top is only required to support snow load and foot traffic. For this situation there are a number of choices:

1. Gable roof with wood trusses.
2. Flat roof with wood joists.
3. Light-duty reinforced concrete slab.
4. Precast roof slabs.

Well-ventilated wood roofs can have a long life on manure tanks even with the expected moisture condition below. The space between the joists or trusses should be adequately ventilated with screened openings to outside. Gable roof trusses can easily span up to 12 m. Wood joists can span up to 4.8 m. A reinforced concrete slab 150 mm thick and with a modest amount of reinforcing will span 3.6 m.

Rectangular concrete tanks should be sized for the capability of the agitation equipment; with tractor pto-drive, tanks should be proportioned so that tank corners are not over 10 m from the agitation nozzle. This limits rectangular tank dimensions to about 7.5 × 15 m.

It is very important that a properly engineered plan be obtained and followed. The walls must hold against the soil pressure when the tank is empty and against the liquid pressure when the tank is full, and the soil dry. The tank should not be backfilled until a least a month after the construction, and the fill should be placed and compacted in layers.

Circular concrete tanks (ref. 17) can be constructed below or above ground. Because of their shape, they make more efficient use of the strength of reinforced concrete to resist both the soil pressure and the liquid pressure. And because a top is not required to support circular walls, precast concrete silo staves may be used for small diameters (up to 7.2 m). Below-ground circular tanks range from 6 to 15 m in diameter and up to 4.2 m deep. Above-ground circular tanks can be constructed to a height of 9 m. Remember however that liquid manure produces two to three times greater pressure than silage does, so extra steel reinforcing is required. Be sure that your contractor has an engineered plan.

Table 14 lists capacities of circular tanks. Below-ground circular tanks should extend 300 to 600 mm above the ground and be roofed or fenced for safety.

TABLE 14. CAPACITIES OF CIRCULAR MANURE TANKS

Tank diameter (m)	Capacity (m^3/m depth)
6	28.27
9	63.62
12	113.1
15	176.7
18	254.5
21	346.4
24	452.4

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